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# Trends of Rainfall and Rice Yield of Cities in Punjab

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**Abstract:- India, and specifically Punjab, has been one of the major players in the rice trade, and its exports can be considered a necessity. However, at the same time, climate change has played an important role in changing the production of agricultural crops. We know that climate change has caused an impact on temperature of different regions, precipitation, and monsoon patterns. This research paper aims to find the trend relation between precipitation and rice yield of the five most important cities of Punjab. Additionally, this data was collected till the year 2011, and compared the trend over the years using the Mann-Kendall Test.**

## I. INTRODUCTION

Climate change is a pertinent topic that has had both a robust impact on the environment as well as the economy. Furthermore, it has impacted the weather, climate, and temperature of multiple locations around the world. Such an impact can be seen in India, as it has evidently changed the yields of agricultural crops – such as rice, and wheat. Rice yields in India are projected to reduce by 20% in 2050 and 47% in 2080 [1]. Multiple studies have shown a correlation between rainfall and rice yields – either showing a positive or negative association [2]. In this research paper, a trend analysis between rainfall and rice yields was conducted for 5, major rice producing, cities in Punjab – Amritsar, Ludhiana, Patiala, Ferozepur and Sangrur, from 1974 to 2011. The trend analysis helps find the trend between the variables, whether it is increasing, decreasing or unaffected. A Mann – Kendall test was set up, and the Mann – Kendall Tau value as well as the Sen's Slope value were found and analysed. Additionally, graphs showing the trend of the data are also displayed in this paper.

## II. STUDY AREA

Punjab is one of the largest producers of rice. From producing 11 million metric tons in FY 2009, Punjab has grown to producing over 12.78 million metric tons in FY 2021 [3]. Bordered by the states of Himachal Pradesh, Haryana, Rajasthan, and union territories such as Chandigarh, as well as Jammu and Kashmir; it is located at 30.79°N 75.84°E. With an area of 50,362 square kilometers, it is India's nineteenth-largest state. It receives over 627 mm average annual rainfall and experiences a variation of over 200 mm rainfall per year [4]. The cities taken are situated in North Punjab (Amritsar), East Punjab (Patiala), central Punjab (Ludhiana), West Punjab (Firozpur), and South Punjab (Sangrur) in order to ensure heterogeneity.

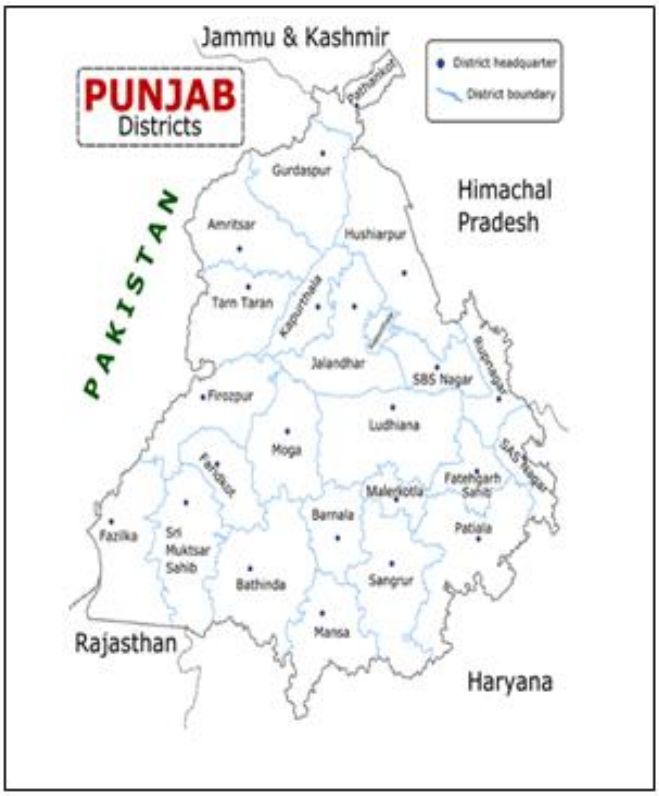


Fig. 1. Map of Punjab

## III. METHODOLOGY

This research paper primarily focuses on carrying out a trend analysis using the Mann-Kendall method. The data sets for rainfall and crop yields were taken into account from 1974 to 2011 for each of the 5 cities. The methods used are presented below:

- *Continuity Correction: This is a process to adjust discontinuous distributions when they are approximated by continuous distributions. This had been taken place before the data had been subjected to any tests.*
- *Mann-Kendall Test: This is a non-parametric test that is used for monotonic trends. This test is usually used on hydrometeorological data, and analyses whether the data values are increasing or decreasing over a certain time period.*

### A. Hypothesis

Using a rank-based procedure, the null hypothesis of the test is that there is no trend in the series. The alternate hypothesis, $H_a$ is that there is a trend in the series. The test

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conducted was a two-tailed test with alpha level (*a*) set at 0.05.

*B. Mann-Kendall Function*

Firstly, the indicator function *sign* $(x_j - x_k)$ can be calculated as follows:

$sign(x_j - x_k) =$

$sign\ (x_j - x_k) = 1$ *{provided:* $x_j - x_k > 0$*}* (1)

$sign\ (x_j - x_k) = 0$ *{provided:* $x_j - x_k = 0$*}* (2)

$sign\ (x_j - x_k) = -1$ *{provided:* $x_j - x_k < 0$*}* (3)

Secondly, the test statistic *S* is calculated:

$$S = \sum_{k=1}^{n-1} \sum_{j=k=1}^{n} sign(x_j - x_k) \quad (4)$$

The variable 'n' represents the sample size; the 'j' represents a value from (1,2,3,4…. n-1); the 'k' represents the values from (1,2, 3…. n)

The VAR(S) calculated as follows.

$$VAR(S) = \frac{1}{18}\ (n(n-1)(2n+1) - \sum_{k=1}^{p} q_k\ (q_k - 1)(2q_k + 5)) \quad (5)$$

Here, n is the data size; p represents the total number of tie groups in the data and $q_k$ is the number of data points in the kth tie group.

Lastly, the Z value is calculated:

$$\frac{S-1}{\sqrt{VAR(S)}} \quad \{provided\ S > 0\} \quad (6)$$

$$0 \quad \{provided\ S = 0\} \quad (7)$$

$$\frac{S+1}{\sqrt{VAR(S)}} \quad \{provided\ S < 0\} \quad (8)$$

The Z value can be interpreted as:

- Positive Z signifies an upward trend.
- Negative Z signifies a downward trend.

*C. Sen's Slope*

This is a non- parametric test used for estimating the slope by computing the least squares regression analysis. The basics of this test are that it slopes for all pairs of ordered points are required, followed by finding the median from these points. If for example, a Mann-Kendall Test reveals a positive test, a Sen's Slope can help determine magnitude to which it is positive.

## IV. RESULT AND DISCUSSION

*A. Summary Statistics (Rainfall)*

TABLE I. SUMMARY STATISTICS FOR RAINFALL (ACROSS THE 5 CITIES)

| City Name | Observations | Min | Max | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Amritsar | 38 | 207.9 | 1233.20 | 544.253 | 232.155 |
| Ferozepur | 38 | 29.80 | 956.20 | 332.026 | 211.104 |
| Ludhiana | 38 | 38.00 | 1242.20 | 545.879 | 222.349 |
| Patiala | 38 | 79.50 | 1060.6 | 663.271 | 244.188 |
| Sangrur | 38 | 00.00 | 997.4 | 412.582 | 240.789 |

*B. MK & Sen's Slope Trend Analysis For Rainfall*

Comparing all of the five cities, we notice a common trend wherein all of them have a decrease in rainfall over the years. A two-tailed interval was set up with an alpha level of 0.05. Analyzing the data, we come to a conclusion that though these cities are situated in different geographical places within Punjab, they have been prone to a decline in trend of rainfall over the time span of 38 years.

TABLE II. TAU AND SEN'S SLOPE VALUES (RAINFALL)

| City Name | Mann Kendall Tau | Sen's Slope |
|---|---|---|
| Amritsar | -0.376 | -10.174 |
| Ferozepur | -0.468 | -12.683 |
| Ludhiana | -0.260 | -6.529 |
| Patiala | -0.155 | -3.720 |
| Sangrur | -0.236 | -8.758 |

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*C. Summary Statistcis (Rice Yield)*

TABLE III. SUMMARY STATISTCIS FOR YIELD (ACROSS 5 CITIES)

| City Name | Observations | Min | Max | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Amritsar | 38 | 1774 | 3108 | 2676.895 | 364.449 |
| Ferozepur | 38 | 2392 | 4157 | 3298.895 | 491.569 |
| Ludhiana | 38 | 2979 | 4962 | 3850.763 | 458.909 |
| Patiala | 38 | 1952 | 4270 | 3341.658 | 516.005 |
| Sangrur | 38 | 1815 | 4696 | 3708.947 | 596.367 |

*D. MK & Sen's Slope Trend Analysis For Rice Yield*

Rice yield is the dependent variable in this study, and its trend has been measured by using the Mann-Kendall Test, as well as the Sen's Slope test. Looking at the data, we, once again, notice a similar trend between the cities and the change observed. Here, in each of the cities, an increase in the rice yield has been seen, considering the time span of 38 years.

TABLE IV. TAU AND SEN'S SLOPE VALUES (RICE YIELD)

| City Name | Mann Kendall Tau | Sen's Slope |
|---|---|---|
| Amritsar | 0.481 | 21.429 |
| Ferozepur | 0.752 | 39.656 |
| Ludhiana | 0.451 | 27.111 |
| Patiala | 0.624 | 36.333 |
| Sangrur | 0.653 | 42.353 |

## V. CONCLUSION

Though it would be impossible to correlate these two variables, just by using the Mann-Kendall Test; one can certainly observe a similar trend in each of the cities of Punjab. Upon finding the data, we notice that each city observed a decrease in the rainfall, yet at the same time harvested an increase in the yield of rice. However, it is also impossible to conclude a correlation as many other factors such as CO2, temperature, humidity, and wind play a role in changing the rice yield [5][6]. Additionally, as Punjab has showed a change in such factors, concluding one factor to be a determinant for the change in rice yield, is impossible.

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