


Application of innovative trend analysis on rainfall time series over Rajsamand district of Rajasthan state

Jinal Pastagia and Darshan Mehta *

Department of Civil Engineering, Dr S. & S. S. Ghandhy Government Engineering College, Surat, Gujarat, India

*Corresponding author. E-mail: darshanmehta2490@gmail.com

 DM, 0000-0001-8418-0026

ABSTRACT

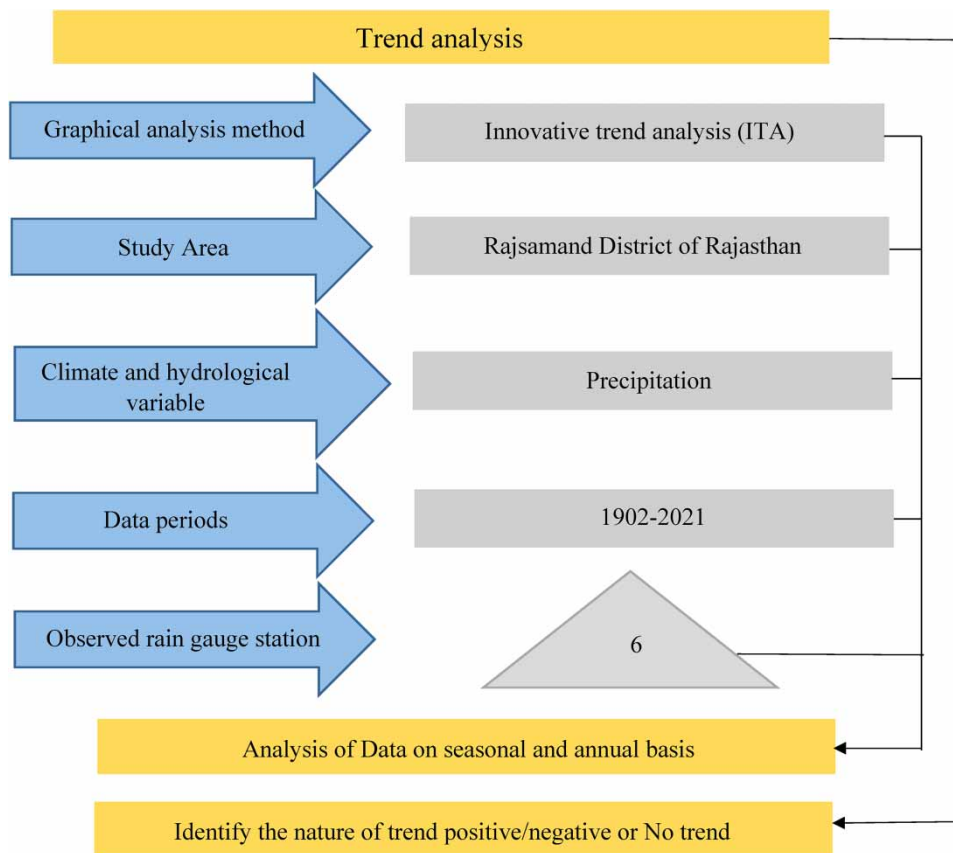
Rainfall is an important part of the hydrological cycle, as well as its variability, and is relevant to drought and floods. Long-term changes in hydrological processes are referred to as climate change for an area. Urbanization, population growth, and economic growth are all having negative effects on the environment. The study of trends in the long term is essential from climatic change and socioeconomic perspectives. Examining the temporal variations in rainfall is crucial because changes in rainfall patterns and distribution can have a significant impact on the amount of water available in a watershed. The objective of the study is to assess the long-term (1902–2021) temporal trends in seasonal (winter, pre-monsoon, monsoon, and post-monsoon) and annual rainfall for the Rajsamand district of Rajasthan state using the innovative trend analysis (ITA) technique. Due to its ability to provide results in graphical form, the ITA approach is a very useful tool for detecting patterns in rainfall time series data. This technique is also used to detect trends as 'low,' 'medium,' and 'high,' which should be considered in future studies on floods 'high' and drought 'low', respectively. Based on the above study, it is observed that no trend is detected for the annual season, a positive trend is detected in the winter season and a negative trend is detected for pre-monsoon and post-monsoon seasons in some regimes respectively. The ITA of the S-W monsoon also specifies that in the low regime the nature of the trend is increasing and in the high regime nature of the trend is decreasing. This research will serve as a scientific foundation for assessing and mitigating the effect of climate change on the environment to reduce the risk of weather patterns.

Key words: climate change, graphical method, hydrological cycle, innovative trend analysis, long-term trend

HIGHLIGHTS

- The innovative trend analysis (ITA) method is used in the study.
- To apply the ITA approach to examine the annual and seasonal patterns of various precipitation intensities in Rajsamand.
- To discuss the patterns of seasonal and annual rainfall variability across the region.
- ITA method is a very useful tool for detecting patterns in rainfall time series.
- ITA method is both simple and effective.

GRAPHICAL ABSTRACT



INTRODUCTION

The most important climatic variables in terms of climate change impacts are rainfall and temperature (Pingale *et al.* 2014). Urbanization, population growth, and economic growth are all having negative effects on the environment (Mehta & Yadav 2021b). Problems associated with climate change are growing more severe as cities grow, as more pervious areas become impervious, resulting in decreased foliage cover and higher temperatures (Pingale *et al.* 2016). Rainfall is an important aspect of the hydrologic cycle, and variations in its pattern have a direct impact on the region's water resources (Goyal & Surampalli 2018). Agriculture accounts for 17–18% of India's overall GDP Banda *et al.* 2021.

Agriculture is the most common occupation, with 60% of the population operating in it (Alashan 2018; Bouklikha *et al.* 2021). The agro-economy in nations such as India is heavily reliant on precipitation patterns and also on irrigation. One of the most serious worries about climate change is that total, Spatio-temporal changes in precipitation will increase in many regions of the world (Kundzewicz *et al.* 2019). A poor or low monsoon has always been seen as a major setback to India's economy, resulting in a fall in the country's GDP levels (Singh *et al.* 2021). In its fifth assessment synthesis report, the Intergovernmental Panel on Climate Change (IPCC) made it absolutely clear that the climate system is warming, and many of the observed changes since the 1950s were unexpected (Jain *et al.* 2013; Caloiero *et al.* 2020).

In the IPCC's fourth assessment report, it was also noted that the current evidence of actual melting of ice and snow, rises in global average ocean temperatures, and rising global sea levels clearly indicate that the climate system is warming (Singh *et al.* 2021). Lack of water is a major threat to both humans and nature, especially in arid and semiarid regions (Aher & Yadav 2021). Many researchers have studied the rainfall trend and pattern in the different parts of the country as well as India as a whole (Yildirim & Rahman 2022). The rainfall data for the period of 135 years from 306 rain gauge stations across India indicate a non-significant trend in the annual rainfall (Mehta & Yadav 2021c). Trend analysis is one of the most prominent approaches for assessing the variation of hydro-meteorological variables over the previous

couple of decades, and it has been widely used by researchers (Caloiero *et al.* 2020). Analyzing long-term precipitation patterns and variability is important for long-term water resource management (Caloiero *et al.* 2018). Researchers can describe the spatial and temporal Atmosphere by analyzing trends in precipitation and temperature (Caloiero *et al.* 2020). Analyzing long-term precipitation patterns and variations is critical for long-term water resource management (Malik *et al.* 2019). By investigating precipitation and temperature patterns, researchers can define the spatial and temporal variability of water shortages and manage them for future development (Gedefaw *et al.* 2018). Most trend-detection studies using the Mann-Kendall (MK) test have assumed that sample data are serially independent, although certain hydrological time series such as water quality series and annual mean and annual minimum stream flows may frequently display statistically significant serial correlation. Furthermore, von Storch *et al.* 1995 documented that the existence of positive serial correlation increases the probability that the MK test detects a trend when no trend exists. Despite the MK test's widespread use in hydrology trend analysis, previous research has shown that the presence of autocorrelation can interfere with the ability to detect trends using MK and Sen's slope (Thomas & Prasannakumar 2016). Some studies use a trend-free pre-whitening method to eliminate the autocorrelation in the data series. However, according to a number of studies, pre-whitening may not be effective if serial correlation persists after the first-order autoregressive process and the sample size is large (Gao *et al.* 2020). It can also remove a portion of the actual trend. The innovative trend analysis (ITA) method, which can solve the issue of trend detection in autocorrelated time series data, was proposed as a solution to this problem. Numerous studies conducted all over the world have proven the validity of the ITA method (Caloiero *et al.* 2020).

Many approaches for evaluating the trend of hydro-meteorological variables have been developed and implemented, each with its own range of limitations and advantages (Mehta *et al.* 2021a). Şen (2012) proposed the ITA method, a new non-parametric basis methodology for determining significant trends in time series (ITA). In other words, the ITA method examines the locations of data points in a Cartesian grid to the 1:1 line, which serves as a reference. This technique was used to analyze the trends of a variety of hydrological parameters. Many researchers combined the MK method with an ITA analysis tool for assessing time series. Many studies have utilized various approaches to examine the variability of precipitation, such as the Mann-Kendall (MK) test and wavelet analysis (Singh *et al.* 2021). These earlier approaches, however, are incapable of accurately describing variations in rainfall intensity. A new trend method i.e., the ITA method is used in our study, as it is both simple and effective. This method is also found to accord well with other statistical approaches, demonstrating that it is a practical and useful way of undertaking trend analysis (Caloiero *et al.* 2020). In comparison to other non-parametric approaches, the ITA method is universally applicable, independent of distribution hypothesis, series correlation, seasonal period, or the time series size. Calculating the regional average precipitation will definitely result in a huge error due to the unequal distribution of meteorological stations in Rajsamand. There is an urgent need for an impartial and extensive examination of the precipitation change in Rajsamand to effectively inform decision-making for regional economic growth. The goal of this research is to apply the ITA approach to examine the annual and seasonal patterns of various precipitation intensities in Rajsamand. These studies have significance in both the agriculture and health sectors. The studies reported so far have been focused on flood and drought events in the Rajsamand district. Also, very few studies have concentrated on the annual and seasonal rainfall trend across the Rajsamand district of Rajasthan. To the best of our knowledge, no study in the past has been carried out at the micro-level, by using different time series, i.e., seasonal and annual basis. Using an innovative trend analysis tool, this study discusses the patterns of seasonal and annual rainfall variability across the region.

STUDY AREA AND DATA COLLECTION

Rajasthan's climate is mainly arid or semi-arid, with hot temperatures throughout the year and high temperatures both in summer and winter. Rainfall varies throughout the state of Rajasthan, just like the climate (Mehta & Yadav 2022). The South-western monsoon makes up the majority of the rainfall from July to September. The Rajsamand district is situated in the southern region of Rajasthan State, bounded by the latitudes of 24°46'32" and 26°1'36" in the north and 73°28'30" and 74°18'55" in the east, respectively. It makes up 4,522.26 sq km or 1.39% of the state's total area. It is bordered on the south and southwest by the district of Udaipur, on the east and southeast by the districts of Bhilwara and Chittorgarh, on the north by the district of Ajmer, and on the west by the district of Pali. Seven Tehsils and seven blocks make up the district with a population of around 55,000 people. It is named after a man-made lake that was built towards the end of the 17th century. Because the city is located in a mineral-rich region, mining and agriculture are the two most important sectors of

the local economy. Rajsamand has very little rain throughout the year. The district experiences an arid to the semi-arid type of climate. Normal rainfall (1951–2000) of the district is 554.5 mm whereas average annual rainfall (2001–2021) has been lower than average annual rainfall and placed at 567.8 mm. Almost 92% of the total annual rainfall is received during the southwest monsoon which enters the district in the third or fourth week of June and withdraws in the mid of September. The lowest average annual rainfall 439.67 mm has been received at Rajsamand, which lies in the central part of the district.

Monthly rainfall data were collected from the Indian Meteorological Department (IMD) and WRIS with data length of 120 years (1902–2021). There is a total of 6 gauging stations in Rajsamand districts which is shown in Figure 1.

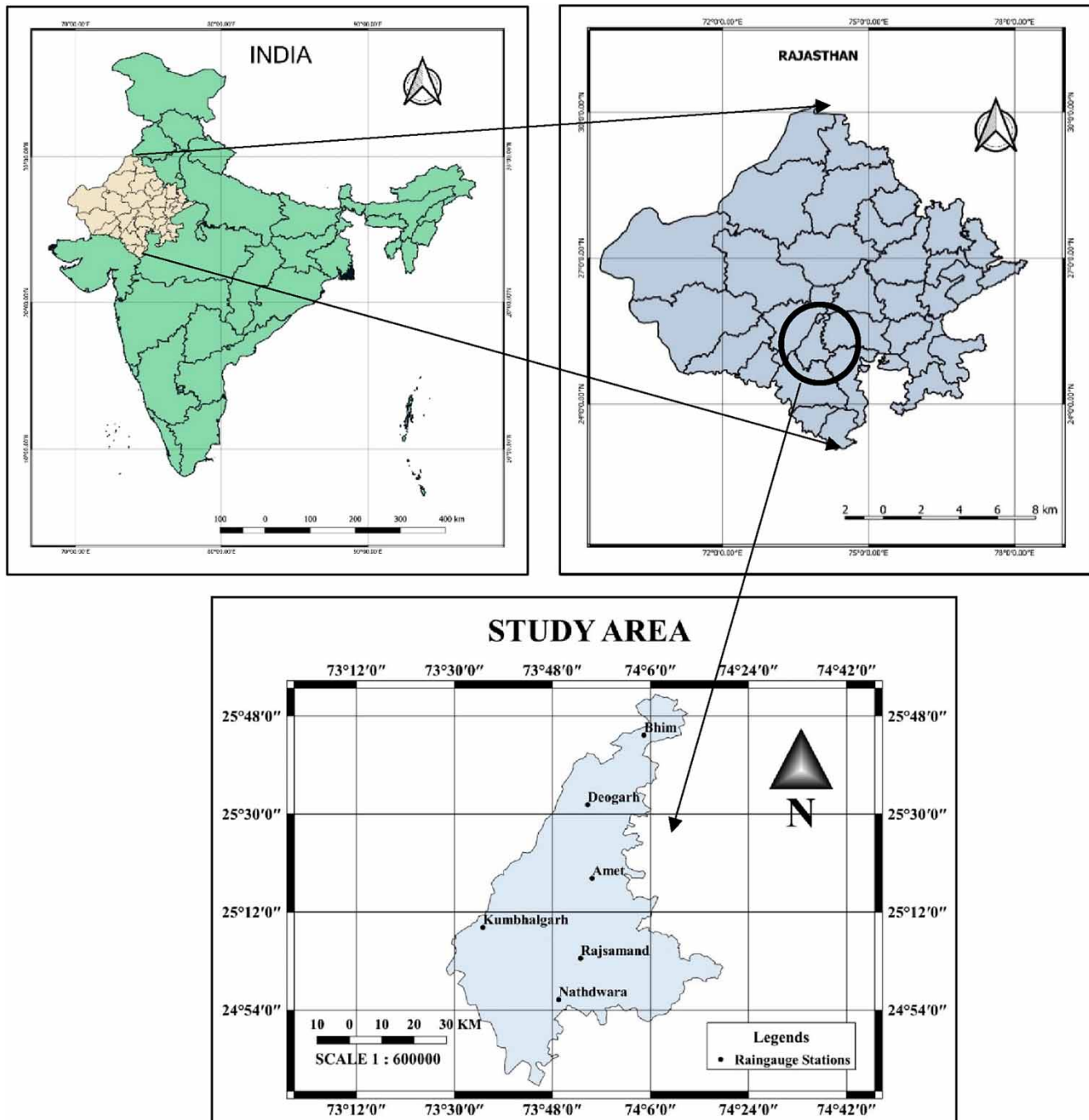


Figure 1 | Study area Map.

METHODOLOGY

The sequencing of the steps involved in the data analysis in the present study is included in the form of a flowchart as shown in Figure 2. In the present analysis, seasonal (pre-monsoon, SW monsoon, post-monsoon and winter) and annual rainfall data for the Rajsamand district of Rajasthan are used. The data are collected from the WRIS portal for a period of 120 years. The data series is prepared in the form of the seasonal and annual time periods. In the present study, ITA analysis was applied to a climatological variable for trend analysis. As per IMD, there are four climatic seasons: southwest monsoon (June-September), post-monsoon (October-December), winter (January-February), and pre-monsoon (March-May). Figure 2 shows the outline of the methodology.

ITA METHOD

Sen (2012) developed the ITA approach for trend analysis of hydro-meteorological data. The first step is to categorize hydro-meteorological time series data into two equal sub-series and rank data independently in ascending order (Wu & Qian 2017). The method is based on the fact that if two-time series are equal, plotting them against each other generates a scatter of points along the 1:1 (45°) line in the grid point system (Sen 2012). The data should be divided into two subs before performing the ITA to any specific time series. The data for each sub-series is then sorted ascending (or descending). Furthermore, the diagram is split into two separate triangles by the 1:1 (45°) axis of no trend which indicates the increasing (area above 1:1 line) and decreasing (area below 1:1 line) time-series data trend (Aher & Yadav 2021). The scattering of the data rises above (falls below) the 1:1 line whenever the monotonic trend is increasing (decreasing) (Sen & Aksu 2021). Similarly, if the data points fall in the upper triangle portion of the 1:1 line, a positive trend is indicated, and if the data points fall in the lower triangular

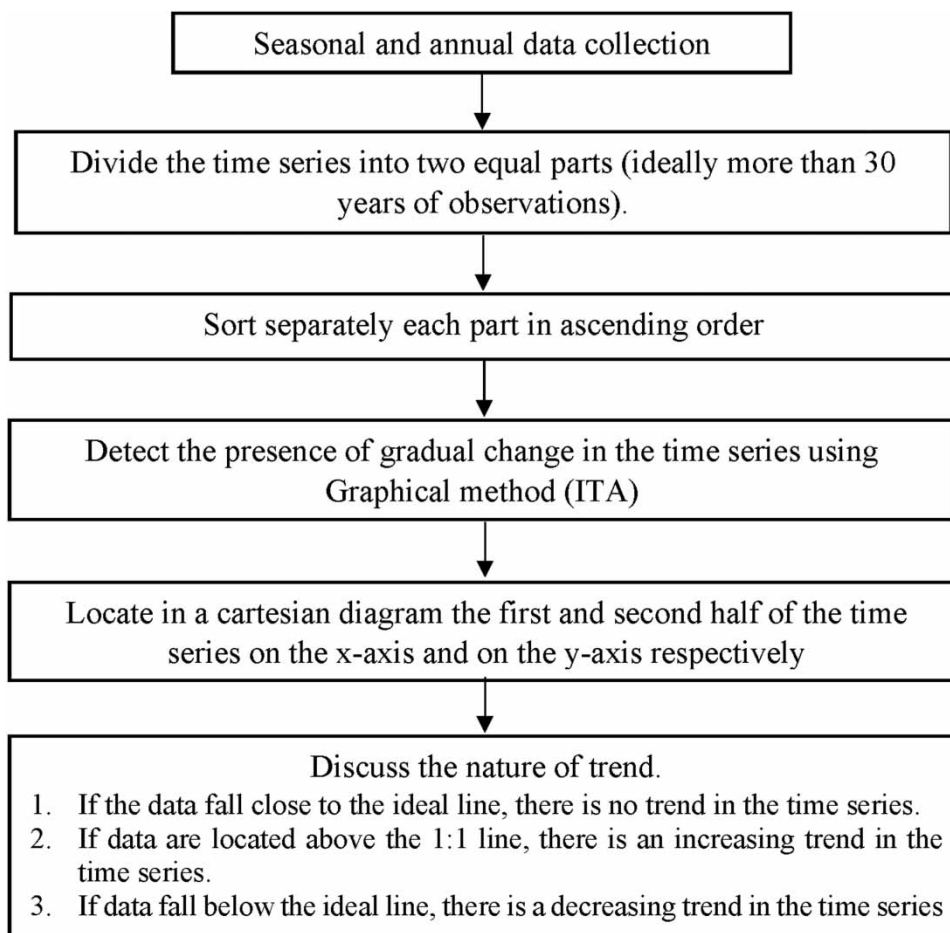


Figure 2 | Flow chart of methodology.

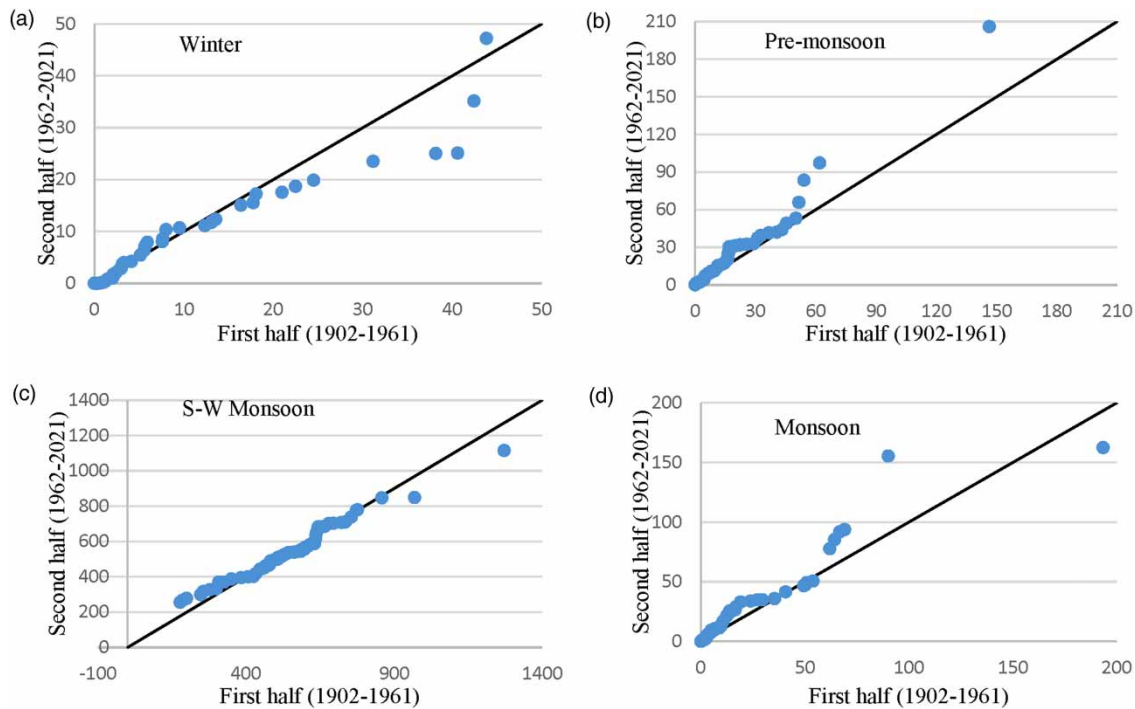


Figure 3 | Various plot 1:1 for (a) Winter (b) Pre-monsoon (c) S-W Monsoon (d) Monsoon.

part of the 1:1 line, a negative trend is indicated (Aher & Yadav 2021). The scatter points displayed on 1:1-line graphs were divided into three verbal clusters for a more comprehensive interpretation: low, medium, and high. ITA can also be used to identify and research the trend of any hydro-meteorological variable's low, medium, and high time-series values.

RESULTS AND DISCUSSION

In this study, Sen's (2012) ITA technique on seasonal and annual rainfall time series of Rajsamand district were used for the purpose of analysis. It is very important to know the impact of climate change over the districts it gives a fair idea about the characteristics of the rainfall pattern. Owing to the overall increase in warmer climate across the globe, it is necessary to

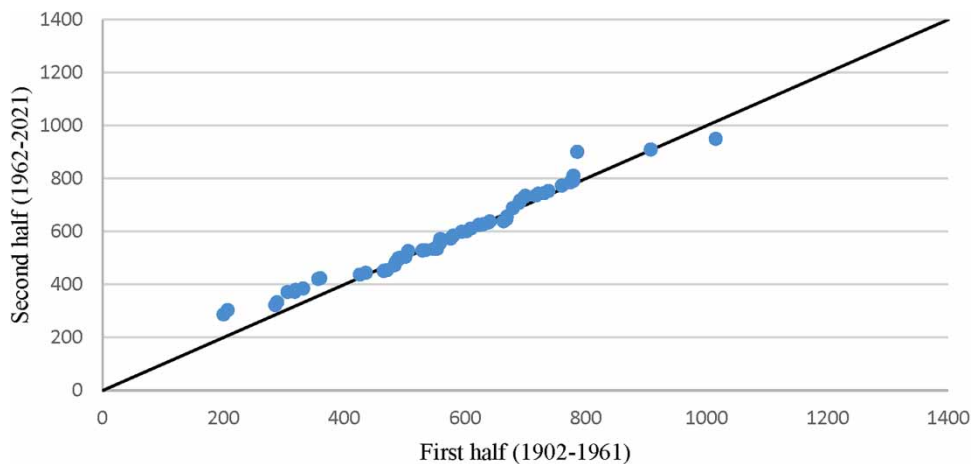


Figure 4 | Various plot 1:1 for annual.

Table 1 | Trend analysis of annual and seasonal rainfall of Rajsamand

	Low	Medium	High
Winter	O	↓	↓
Pre-monsoon	O	↑	↑
S-W monsoon	↑	O	↓
Post-monsoon	O	↑	↑
Annual	↑	O	O

↑ Rising trend, ↓ Falling trend, and O indicates no trend.

check the impact of the increase in temperature on the regional scale also. Now, to check the impact of climate change on rainfall, it is very much important to study the long-term rainfall pattern.

The ITA plots (Figures 3 and 4) are grouped into three types: low, medium, and high. The nature of the trend is shown by each region. The pre-monsoon, post-monsoon, and annual rainfall trends are all positive, whereas the winter rainfall trend is negative in the medium and high regimes. The high regime reported the most negative trend when compared to the low and medium regimes. For seasonal and annual time series, the ITA results show that the nature of the trend is either rising or no trend in the low regime (Table 1).

CONCLUSION

In this research study, seasonal and annual trends of rainfall over the Rajsamand district for the period of 1902- to 2021 (120 years) were assessed by ITA. Climate change has a negative impact on the rainfall pattern in the study area, as well as the entire water supply. The precipitation trend reported in this area may indicate that certain changes are more pronounced than others. The results of the ITA application indicated a seasonal negative trend in winter anomalies for medium and high regimes, but no trend for low regimes. An increasing trend was detected for pre-monsoon and post-monsoon in two categories. Particularly, in the monsoon season, increasing, no trend, and decreasing trend was observed for three different categories. Furthermore, the use of graphical techniques, such as the ITA method, is new in that it overcomes issues such as the independent structure of the time series, normality of the distribution, and data length, all of which may arise when evaluating a large range of data scale. The results of this research will benefit policymakers in the systematic development of present water resources. The above information may be used to make qualitative predictions about when the rainy season will start and how long it will last for the respective river basin.

FUNDING

This research received no external funding.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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