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Application of Turning Point Test to Precipitation Time Series over Seonath River Basin, India

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A B S T R A C T

Precipitation is a very important parameter to estimate climate variability. This paper presents an application of Turning point test to seasonal and annual precipitation data for a period of 30 years over Seonath Basin, a major sub-basin of Mahanadi River Basin. The objective of the application of Turning point test is to catch the randomness of the precipitation time series over the study area. The randomness of precipitation data is checked in general before the trend analysis. The precipitation time series possessing more randomness may give misleading results for trend analysis. Considering this issue, the monthly data was collected for 39 stations, which were categorized into 4 seasons of the year i.e. winter, pre-monsoon, monsoon and post-monsoon. The results reveal for almost all the stations showing insignificant randomness for monsoon, post-monsoon and annual precipitation time series. However, in the winter and pre-monsoon seasons, about half of the stations are showing significant randomness.

Keywords: Turning point test, Precipitation, Seonath Basin, Trend analysis, Statistical hydrology

1. Introduction

A majority of population in India directly depends on agriculture. As agriculture is being excessively dependent on rainfall during monsoon season (June-September), the rainfall anomalies have substantial influence over economy of the country (Dayal et al. 2019; Kruger 1999; Sahoo et al. 2021, 2022; Sharma et al. 2020; Swain 2014, 2017; Swain et al., 2015, 2021b; Verma et al., 2016). It also adds threat to the food security of the nation. Moreover, owing to the poor adaptabilities and inadequate preparedness, the developing countries like India will have to face detrimental effects of climate change (Aadhar et al. 2019; Bahita et al. 2021a, 2021b; Gosain et al, 2006; Nandi et al. 2024). The problems will be further added by anthropogenic activities (Swain et al. 2018b, 2022a, 2022c, 2022h). Moreover, climate change leads to several problems like droughts (Swain et al. 2017b, 2019b, 2020a, 2020b, 2021a, 2021c, 2022b, 2022i, 2023), floods (Gupta et al. 2021, 2022; Patel et al. 2022), groundwater depletion (Dhal and Swain 2022; Sahoo et al. 2021; Swain et al. 20222f, 2022j, 2022k, 2022l), heatwaves (Nandi and Swain 2023; Sahoo et al. 2022; Swain et al. 2022), and other hydrometeorological and socioeconomic consequences. Considering these issues, assessment of climate change and its impacts is necessary, which requires a precise quantification at first. Some studies on rainfall estimations are visible in recent literature (Swain et al. 2017a, 2018a). Rainfall variations have been analyzed across different parts of globe in the last two decades (Afzal et al. 2011; Baniasadi et al. 2023; Bhakar et al. 2006; Che Ros et al. 2016; Chonge et al. 2015).

Several studies have been carried out to estimate the extent and impacts of changing climate in Indian context (Rana et al. 2022; Sharma and Saha 2017; Swain et al. 2019a, 2022d, 2022e, 2022g). Rao (1993) performed trend analysis of rainfall and temperature over entire Mahanadi basin for 1901-80 to assess the climate variability. The effects of global warming on agriculture over 5 districts of Maharashtra was assessed by Deshmukh and Lunge (2012) by applying the correlation and regression analysis methodology on the precipitation data available. A significant decrease in the rainfall during southwest monsoon was observed. The variation of temperature and rainfall over whole India during twentieth century was quantified by Jain and Kumar (2012) using the ubiquitous Mann-Kendall and Sen's Slope Estimator test. Although the temperature was found to be increasing over whole India, the rainfall possessed significant trend for a very few stations. Jain et al. (2013) carried out conventional Mann-Kendall test to detect rainfall trends over North Eastern part of India for the period 1971-2010, inferring the overall trend to be insignificant.

Most of the studies on climate change over India have carried out trend analysis. But the results of trend analysis may not give proper information if the randomness in the data is there to a remarkable degree. Therefore, the test for randomness should be performed before carrying out trend analysis. Several studies exist on application of turning point tests in recent years (Bernardino et al. 2020; Chatterjee et al. 2013; Getahun et al. 2021; Hsieh and Chen 2009; Mersin et al. 2022; Rashid et al. 2015; Rizalihadi 2002; Shao et al. 2010; Shimoda et al. 2018). This study aims to carry out trend analysis of rainfall over a river basin scale in India.

2. Study area and data

The area under investigation for this study is Seonath basin, which lies completely within the state of Chhattisgarh. This location of the basin is between 20° 16' N to 22° 41' N Latitude and 80° 25' E to 82° 35' E Longitude. Being the largest tributary of Mahanadi river, a large portion of the upper Mahanadi valley is occupied by Seonath basin. The length of Seonath river is 380 kilometers with a basin area of about 30500 square kilometers (Verma et al., 2016). The average annual rainfall over the basin is about 1100-1200 mm. The shape of Seonath Basin along with the location of raingauges in the basin is shown in Fig.1 below.

Fig. 1 – Seonath Basin with the raingauges and their corresponding Thiessen polygons

The monthly rainfall data was collected for 39 stations over Seonath basin for 30 years i.e. 1981-2010, from Water Resources Department, Chhattisgarh and Central Water Commission, Bhubaneswar. The data is then categorized into four seasons i.e. Winter (January-February), Pre-monsoon (March-May), monsoon (June-September) and Post-monsoon (October-December). The turning point test is then applied to the seasonal rainfall and annual rainfall over 30 years. The raingauges and their corresponding Thiessen polygons within the Seonath Basin area is shown in Fig. 1.

3. Method (Turning point test)

The methodology used for this study is Turning Point Test. This is a statistical method used to check the randomness of data. If a data series is more random, then there will not be any trend in that series because, trend refers to changes in any particular direction. In this test, the data series is plotted having N number of total data points and number of peaks as well as troughs in the plot are determined. The total number of turning points, P is the sum of number of peaks and troughs. The detailed calculation procedure is given below.

$$Mean, E(P) = \frac{2}{3}(N-2) \quad (1)$$

$$Variance, Var(P) = ((16N-29)/90) \quad (2)$$

$$Standard\ Normal\ Variate, Z = \frac{P-E(P)}{\sqrt{Var(P)}} \quad (3)$$

The magnitude standard normal variate i.e. modulus of Z is a measure of randomness of the data points. If mod(Z) > 1.96, then the data series is said to be random. So even if a trend will be obtained for such cases, the trend may not actually be there.

4. Results and discussions

The results of Turning Point test for seasonal rainfall for all the stations is shown below in Figure 2. The areas marked red are having mod(Z) ⩾ 1.96 and that of marked blue are having mod(Z) < 1.96. Hence, the areas marked red are having more randomness of data i.e. even if these stations may show some trend, but that will not be actually in a particular direction. Due to extreme randomness, there might be a greater value of the Turning point statistic Z.

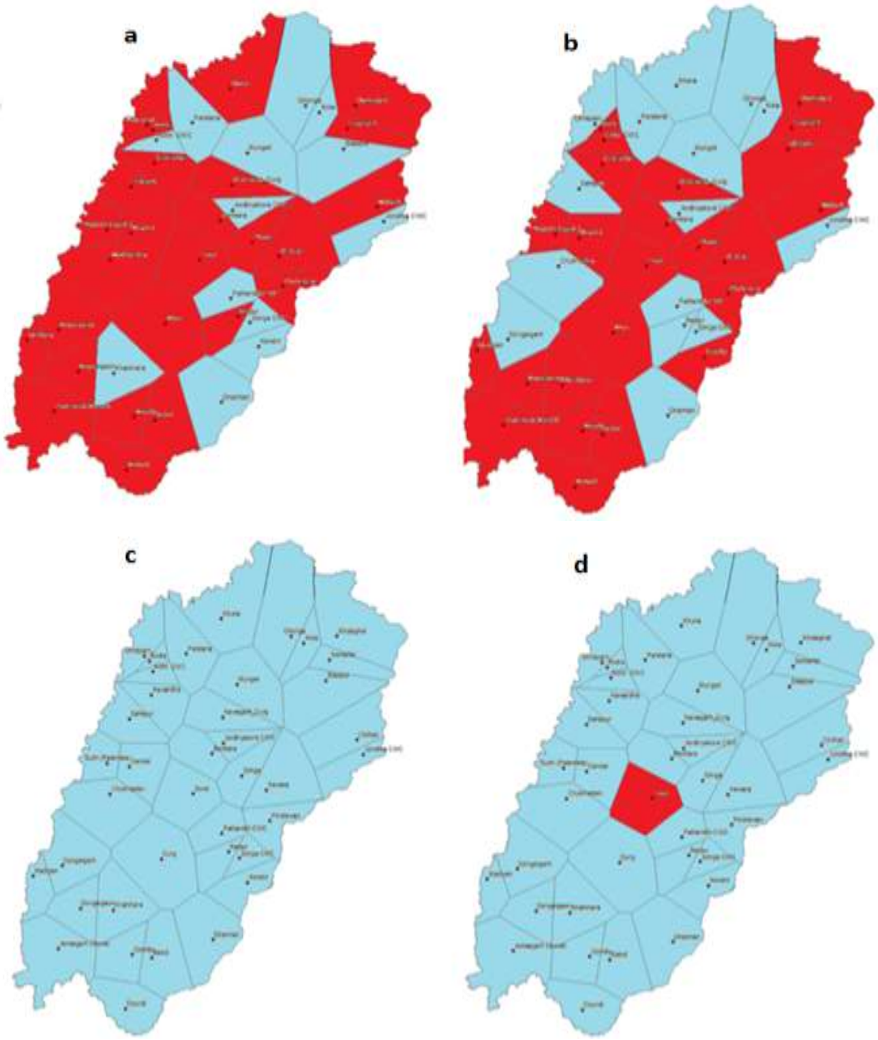

Fig. 2 – Turning Point test results for rainfall data in (a) winter season; (b) pre-monsoon season; (c) monsoon season; (d) post-monsoon season

From the results of turning point test, it is observed that the stations are showing a very high randomness for winter and pre-monsoon phases, whereas for rainfall during monsoon and post-monsoon seasons, almost all the stations are showing no randomness. Hence, application of statistical tests for trend detection is advisable to these data only.

The results of Turning point test for annual rainfall for all the stations is shown below in Figure 3. Similar to monsoon and post-monsoon seasons, almost all the stations are showing no randomness for annual rainfall. Hence, application of statistical tests for trend detection is advisable to annual rainfall time series. Having fewer turning points in annual rainfall data can be beneficial for trend detection in several ways: Simplicity: A trend with fewer turning points is simpler to interpret and model. It allows for clearer visualization and easier communication of the trend's direction over time. Robustness: Trends with fewer turning points are often more robust against noise or short-term fluctuations in the data. This robustness makes it easier to distinguish between the underlying trend and random variability. Reliability: With fewer turning points, there's less ambiguity in determining the direction and magnitude of the trend. This enhances the reliability of trend detection methods and the confidence in the results obtained. Ease of Forecasting: Trends with fewer turning points are typically easier to forecast because they exhibit smoother patterns. Forecasting models can more accurately capture the trend's behavior and make predictions for future periods. Policy and Planning: A clear and stable trend in annual rainfall data with fewer turning points provides policymakers and planners with more reliable information for decision-making. It allows for better long-term planning in areas such as water resource management, agriculture, and infrastructure development. Resource Allocation: Organizations and governments can allocate resources more efficiently when trends are clear and stable. This includes investments in drought preparedness, flood mitigation, and other measures to address the impacts of changing rainfall patterns. In summary, having fewer turning points in annual rainfall data simplifies trend detection, enhances reliability, and facilitates better decision-making and resource allocation in various sectors affected by precipitation patterns.

Fig. 3 – Turning Point test results for annual rainfall data

The turning point test in time series analysis is beneficial for several reasons: Identifying Changes: It helps in identifying significant changes or shifts in the behavior of a time series. These changes could indicate shifts in trends, seasonal patterns, or other underlying dynamics. Forecasting Accuracy: By identifying turning points, analysts can adjust their forecasting models accordingly. Recognizing when a series is likely to change direction can lead to more accurate predictions. Policy Implications: For economic or social time series, identifying turning points can have significant policy implications. Governments and policymakers often use these insights to make informed decisions regarding economic interventions or social programs. Risk Management: In financial markets, identifying turning points can be crucial for managing risk. Recognizing when a market is about to change direction can help investors adjust their strategies to mitigate potential losses or capitalize on emerging opportunities. Statistical Analysis: Turning point tests provide statistical evidence of significant changes in a time series. This evidence strengthens the analytical rigor of studies or reports that rely on time series data. Overall, turning point tests enhance understanding, prediction, and decision-making in various fields by identifying critical shifts in time series data.

5. Conclusions

The randomness of a rainfall time series may mislead the results of conventional methods of trend analysis. Therefore, it is necessary to check the degree of randomness of rainfall data. The application of Turning point test to seasonal and annual rainfall data for a period of 30 years over Seonath river basin, Chhattisgarh, India, has been presented in this article. The results reveal for a very high randomness for winter and pre-monsoon phases, whereas almost no randomness for rainfall during monsoon and post-monsoon seasons as well as annual rainfall. Hence, further application of trend detection methods should be carried out on monsoon, post-monsoon and annual rainfall only.

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