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Short Communication

Application of innovative trend analysis for rainfall variability in the middle catchment of Mahanadi River basin, India

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Climate change effects are visible in various sectors like influencing water availability, agricultural productivity and the overall ecosystem sustainability. Rainfall trend analysis can be used to study effect of climate change on hydrological responses, thereby ensuring adoption of resilient measures for minimizing the adverse effects of climate change on agriculture and allied sectors. For trend analysis, the Mann-Kendall (Mann 1945; Kendall 1948) test and Spearman's rho test (Sen 1968) are widely used, particularly in hydrological studies, due to their nonparametric nature. These methods have been favoured for identifying the monotonic trend data without requiring the data to fit into a normal distribution. However, these tests have limitations, such as assumptions of serial independence and sensitivity to sample size and variation within the time series. Moreover, Yue and Wang (2002) highlighted that the power of these tests is influenced by various factors, including the trend's magnitude, sample size, and the series' variance, which could affect their effectiveness in accurately detecting trends.

In response to the limitations of traditional trend analysis methods, this study adopts the_innovative trend analysis (ITA) technique (Şen, 2012). This approach aims to provide a more robust means of identifying trend in hydrological data. It seeks to overcome challenges associated with serial correlation and the non-normal distribution of data, thereby enhancing the accuracy of trend detection. Singh *et al.,* (2021) used ITA for rainfall trend analysis for western Maharashtra region. In the present study, the innovative trend analysis (ITA) method was employed for identifying and characterizing trend in annual and seasonal rainfall in Kantamal catchment. Such analysis may show a path for water resource planning and management in the catchment under the influence of climate change.

Study area

Kantamal catchment of Mahanadi River basin encompasses a vast area of 20,023 km^2 (Fig. 1). This represents approximately 12.85% of the total geographical area of the Odisha state. The catchment's geographical coordinates extend from 82° 02′ 11″ E to 84° 18′ 56″ E in longitude and from 19° 16′ 7″ N to 20° 44′ 12″ N in latitude. Around 95% of basin area lies within Odisha's territory, with a small portion spreading into Chhattisgarh.

Data collection and processing

The research made use of daily gridded rainfall data with a geographic resolution of 0.25° by 0.25° that span 122 years, from 1901 to 2022, and were provided by the India Meteorological Department (IMD) in Pune (Pai *et al*. 2014). The whole basin is covered by 27 rainfall grids stations and underwent a thorough assessment to find any missing data values. Using the IMD categorization, rainfall trend analysis was done for the pre-monsoon (February - May), monsoon (June - September), and post-monsoon (October - December and January) periods.

Innovative trend analysis (ITA)

The innovative trend analysis method (Şen, 2012) offers a graphical non-parametric approach for detecting both monotonic and sub-trends within time series data. This method allows for the identification of varying trend patterns across different time periods through the analysis of ITA graphs (Pour *et al.,* 2020). It is adept at handling data with autocorrelation and outliers. To conduct ITA, the process begins by dividing the monthly rainfall data into two equal parts. These sub-series are arranged in ascending order and

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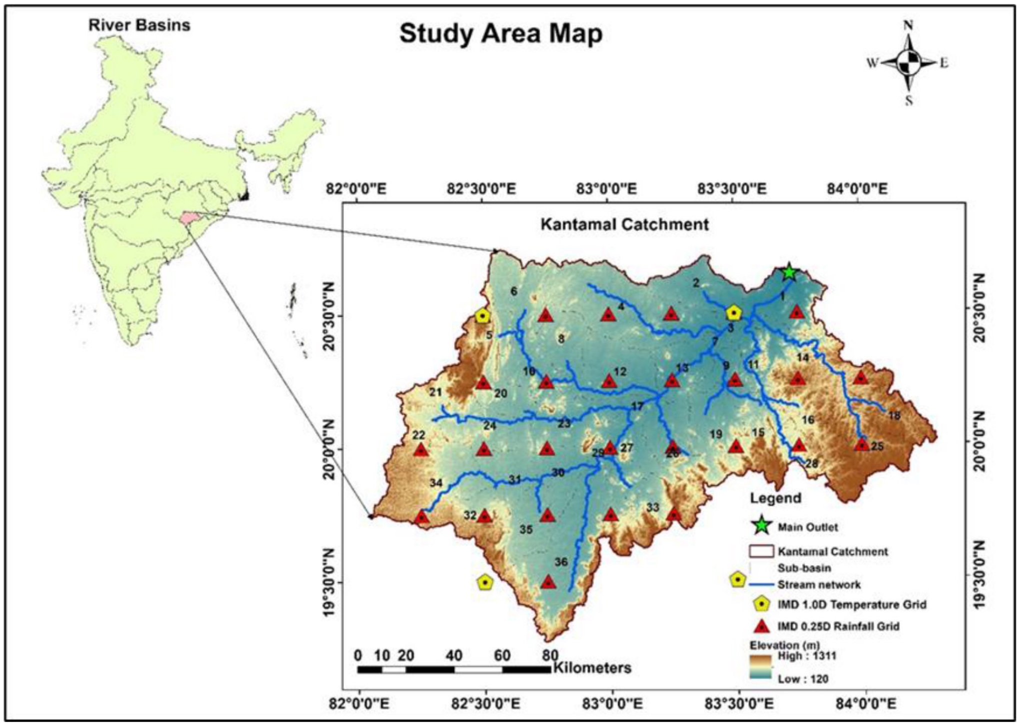

Fig. 1: Kantamal catchment location map

plotted against each other on a Cartesian coordinate system (Girma *et al*., 2020), with the first half on the X-axis and the second on the Y-axis. Next, a straight line is fitted to the scatter plot to show if a "monotonic trend or no trend" is present. If the data points cluster above the 45° line (1:1 line), an increasing trend is shown; if they fall below this line, a decreasing trend is indicated (Cui *et al.,* 2017). Data points aligned along the trend line signal the absence of a trend (Şen, 2012). The ITA slope is calculated using the formula:

$$B = \frac{1}{n}\sum_{i=1}^{n}\frac{10(x_j - x_k)}{\bar{x}} \quad (1)$$

Where n = individual sub-series, B = ITA slope, and are the values of the subsequent sub-series, and x = mean of the 1st sub-series (). In contrast, the significance of ITA is estimated using the probability distribution function (PDF). When the ITA slope's standard deviation () is at a significance level of α, and the confidence interval of a standard normal PDF has a mean of zero, the confidence limit of trend is:

$$CL_{(1-\alpha)} = 0 \pm S_{ITA^{\sigma_s}} \quad (2)$$

Where, = slope standard deviation, which is computed as follows:

$$\sigma_s = \frac{2\sqrt{2}}{n\sqrt{n}}\sigma\sqrt{1 - \rho_{\bar{y}_1\bar{y}_2}} \quad (3)$$

Where, = cross-correlation coefficient between the ascending sorted two halves' means of the series.

When the evaluated slope of the trend of ITA exceeds the critical value, the null hypothesis is rejected. However, this study accounts for the 95% level of confidence.

Trend in rainfall

The innovative trend analysis (ITA) applied to the Kantamal catchment area indicates a complex pattern of rainfall trends across different seasons. The annual and monsoon trends show a non-significant decrease in rainfall, with significant increase concentrated at one location in the southern parts of the catchment (Fig. 2a and 2b). In Odisha portion of the catchment has witnessed decrease in rainfall, however, Gariabandh district of Chhattisgarh has experienced continuous increase in both annual and seasonal rainfall. During monsoon, the variation in rainfall pattern is high in majority of stations as shown in Fig. 2b. During the pre-monsoon season, there is a notable decrease in rainfall in several grid stations, however, at three stations there is significant decrease in pre-monsoon rainfall (Fig. 2c). Predominantly in the western part of the catchment has the higher chances of facing rainfall deficit.

In the post-monsoon season, all the 27 grid stations have shown decrease in rainfall (Fig. 2d). At 11 grid stations, there is significant decrease in rainfall mostly at western and eastern part of the catchment. This is not a suitable indicator for *rabi* crops as the decrease in post-monsoon rainfall will create further moisture stress and will decrease the *rabi* crop production. The post-monsoon rainfall has shown a significant decrease in 40.74% area across the catchment, suggesting rainfed agriculture would be highly affected, with potential reductions in crop yield and increased vulnerability to crop failure.

Overall, the innovative trend analysis of rainfall in Kantamal catchment area has highlighted significant seasonal variations that carry implications for judicious water resource management and sustainable agriculture. The annual and monsoon seasons are characterized by a general, albeit non-significant, decline in

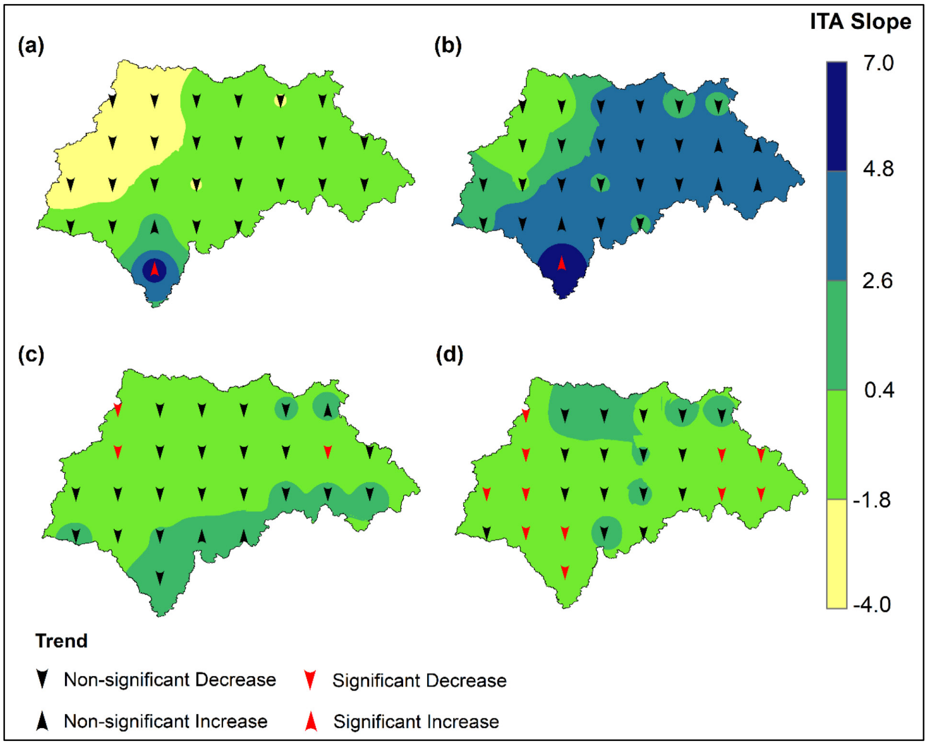

Fig. 2: Slope of innovative trend test of rainfall time series (a) annual, (b) monsoon, (c) pre-monsoon, (d) post-monsoon

rainfall, with notable exceptions in the southern regions where there is significant increase. Decrease in rainfall in pre-monsoon indicate difficulty for summer ploughing. In the post-monsoon, significant decrease in rainfall across the catchment points to potential issues of moisture stress for *rabi* crops. So, development of adequate irrigation potential is highly required in the catchment for sustainable production of *rabi* crops. Monsoon rainfall is decreasing mostly non-significantly over the catchment however; the rate of decrease is prominent in major part of the catchment. This promotes adaption to advanced water management practices in *kharif* rice in the catchment.

This study serves as a call for policymakers and stakeholders in the Kantamal catchment to consider these varied seasonal trends in their water management strategies. This also revealed that the effect of climate change is region specific and mostly observed at micro-climatic situation. It also highlights the need for continuous monitoring of rainfall patterns to better understand the impact of broader climatic factors and to mitigate the effects of these changes on local communities, agriculture, and ecosystems.

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