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Short communication

Innovative trend analysis of monsoon season rainfall of Kerala state

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Kerala is a maritime state, located in the southern part of India. The onset of monsoon in Kerala initiates the Indian summer monsoon which is vital for India's agricultural economy and rainfall distribution (Pattanaik and Bushair, 2024). It marks the shift from dry to rainy season, influencing the time and period of monsoon rain nationwide (Pradhan *et al.,* 2017). The state's agricultural economy heavily depends on summer monsoon rainfall (SMR). The SMR in the state is also an important source of freshwater. Any significant change in the SMR may impact crop growth and freshwater availability, hence, it becomes important to study the trend pattern of the SMR in the region. Trend analysis involves using statistical methods that identify the trend in the data. A statistically significant negative trend indicates reduced rainfall over time, which impacts crop growth and freshwater availability. In contrast, a statistically significant positive trend indicates increased rainfall, influencing water resource management and ecosystem sustainability. Administrators also benefit from understanding rainfall patterns as it facilitates informed decisions on water resource allocation, while it is helpful to farmers in strategic crop planning.

Various statistical methods, viz., Mann-Kendall (MK) method, Sen slope (SS) method (Shankar and Sharma, 2025) Spearman's rank correlation method, modified Mann-Kendall method (MMK) (Ghanim et al., 2023), sequential Mann-Kendall method (SQMK), discrete wavelet transform (DWT) method, innovative trend analysis (ITA) method (Al-Lami et al., 2024), have been used to detect the trends in rainfall. Adarsh and Janga Reddy (2015) used the MK, SS, SQMK, and DWT tests for the detection of trends in the rainfall pattern of four subdivisions in southern India. By analyzing the data of 140 years (1871–2011), they have found an increasing trend in the rainfall for all the subdivisions except Kerala, in which a decreasing trend has been found for seasonal and annual rainfall (Adarsh and Janga Reddy, 2015). Nikhil Raj and Azeez (2012) analysed the trends in the rainfall pattern of the Bharathapuzha river basin of Malabar Coast of Kerala using the MK test and wavelet analysis, and found that there is a decreasing trend in the rainfall. These studies, specifically of Kerala, give insight into the overall rainfall pattern in the region. In all these localized studies, recently developed methods like the MMK test and ITA methods have not been used.

In this present study, trend analysis has been performed for monthly (June, July, August, and September), seasonal (SMR), and annual rainfall using the MK, SS, MMK, and ITA methods. The monthly rainfall data for the period from 1871 to 2016 of 306 stations covering all 14 districts of Kerala was acquired from the Indian Institute of Tropical Meteorology's website https://www.tropmet.res.in. The statistical analysis was performed using the R software version 4.4.1.

The Mann-Kendall test is a non-parametric test, widely used for checking the presence of a trend in the hydrological data (Kendall, 1975).The null hypothesis of (H_0) of no trend present in the data is tested against an alternative hypothesis (H_1) that a trend is present in the data. The Sens' Slope test is a robust method for detection of trend in the time series data (Sen, 1968). It involves the computation of linear slopes $b_w = \frac{y_v - y_u}{v-u}$ for all possible values of u and v. The Sen's estimator of slope b_{sen} is the median of b_w when time series is autocorrelated, it would cause the trend to be statistically significant when it is not. It occurs because the variance of the MK test statistic (S) is under-estimated if positive auto-correlation is present in the data and it is over-estimated if negative auto-correlation is present. In such a situation, modified Mann-Kendall tests is used. The variance correction is done using the Hamed and Rao approach (Hamed & Ramachandra Rao, 1998).

The Innovative Trend Analysis (ITA) is a graphical method for detecting trends in the data which can be applied to the data regardless of its distribution, data size, and serial correlation.

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Table 1: Mann Kendall's test and Sen's slope test

Period	Mann-Kendall's test		Sen's test	
	Test statistics	P Value	Sen slope estimate	90% confidence interval
June	-0.154	0.00584***	-1.1216	(-1.7186, -0.4613)
July	-0.0872	0.11875	-0.6419	(-1.3538, 0.0376)
August	0.0426	0.44642	0.2141	(-0.2647 0.6647)
September	0.0911	0.10323	0.3961	(-0.0047, 0.7946)
Season	-0.0966	0.08407*	-1.2831	(-2.5855, -0.0628)
Annual	-0.028	0.61768	-0.4462	(-1.9258, 0.9666)

Significance Level: *< 0.10, ** < 0.05, *** < 0.0

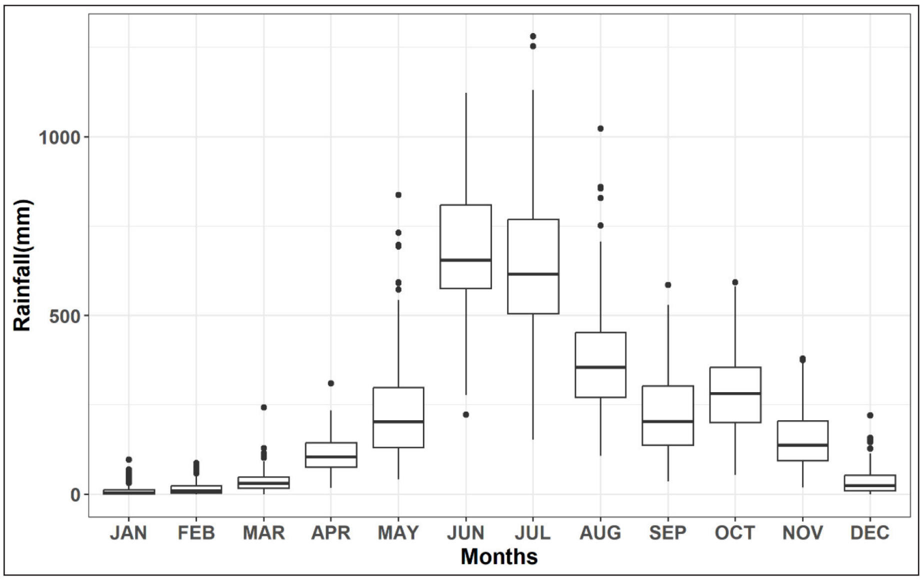

Fig. 1: Boxplot of monthly rainfall

It is proposed by Sen (Şen, 2012). In this method, data points are divided into two halves: the first half and the second half. A scatter plot of the first half of the time series (x-axis) against the second half (y-axis) is drawn. If the plot shows that the data points are on the 45^0 straight line, it means that there is no trend present in the data; however, if data points are above (below) the 45^0 straight line, it means that a monotonically increasing (decreasing) trend is present in the data. If some of the points are above the 45^0 straight line, and some are below the line, it means that the time series is non-monotonic, increasing and decreasing at different time point intervals.

Fig. 1 shows the boxplot of monthly rainfall. The boxplot gives an idea about the skewness in the data. The box in the plot shows the three quartiles, the lower line represents the first quartile (Q_1), the middle line shows the second quartile (Q_2), and the upper line shows the third quartile (Q_3). The vertical line above (below) the third (first) quartile is drawn up to 1.5 times the interquartile range; the points above (below) these lines may be considered as upper (lower) extremes. The plot shows that the maximum rainfall is observed in June, followed by July, whereas the least rainfall is received between December to March. A significant portion of the annual rainfall is received between May to November. For June, July, September, April, and November, the rainfall is positively skewed, which means that the highest rainfall is received during the initial phase of the study period in comparison with the latter; for the remaining months, it is approximately symmetric.

The results of the MK and SS tests are shown in Table 1**.** The trend value for June and the season is decreasing, as well as statistically significant according to both tests. For July, August, September, and Annual rainfall, the trend values are statistically insignificant. Table 2 shows the results of the modified Mann-Kendall Test. The trend value for June, July, and the season, are decreasing and statistically significant, whereas it is decreasing and statistically significant for September.

Fig. 2 displays the ITA plots for June, July, August, September, season, and annual rainfall. For the ITA plot for June and July, all points fall below the lower 90% confidence interval, indicating that there is a decreasing trend in the rainfall amount in the second half as compared with the first half, which is an indication of water scarcity in the future. For August, low (200mm to 400mm) rainfall values fall above the 1:1 line which indicates that there is an increasing trend, the medium rainfall values (400m to 600mm) fall near the 1:1 line indicating the absence of trend, the

Table 2: Modified Mann-Kendall test

Period	n/n_s*	New variance	Corrected Z	New P-value	Old P value
June	0.40972	143119.99	-4.3060	0.00002***	0.00585
July	0.49300	172208.02	-2.2218	0.02630**	0.11875
August	0.85851	299883.23	0.8217	0.41122	0.44642
September	0.75343	263175.89	1.8772	0.06050*	0.10323
Season	0.68896	240656.74	-2.0813	0.03741**	0.08407
Annual	1.06251	371139.49	-0.4842	0.62822	0.61768

Significance Level: *< 0.10, ** < 0.05, *** < 0.01

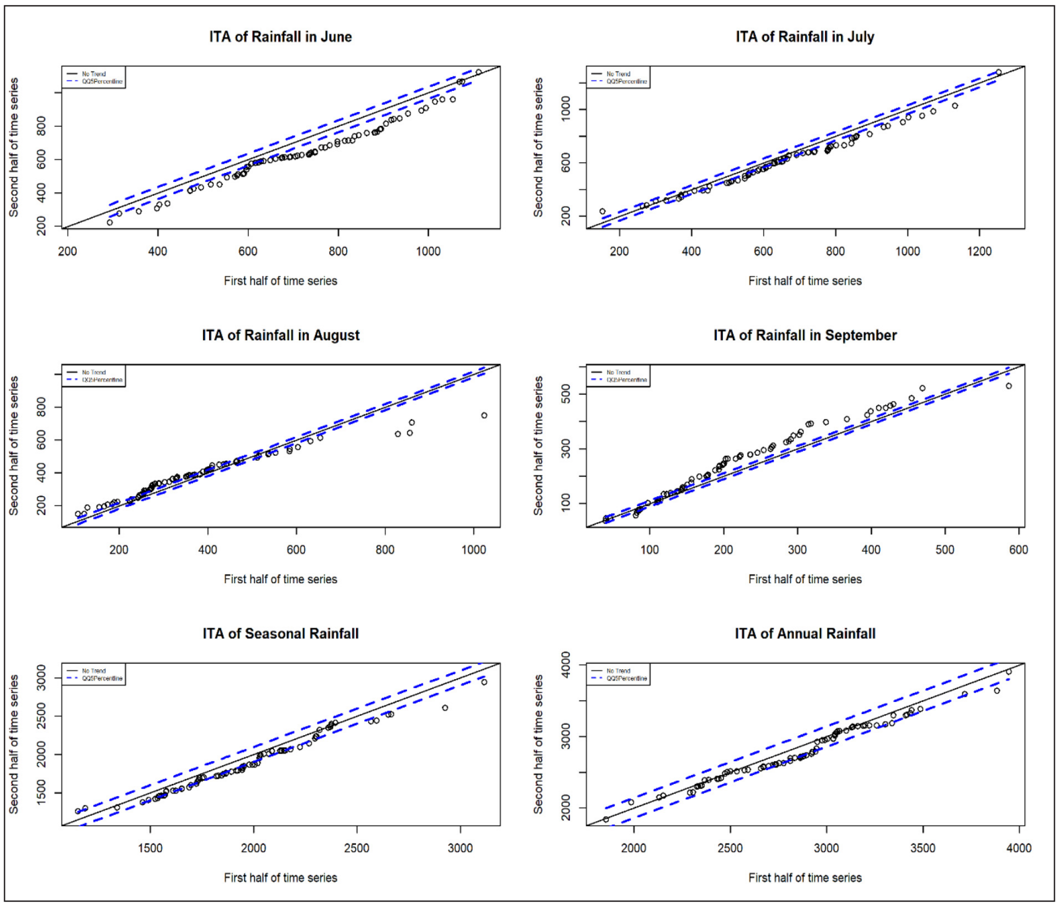

Fig. 2: Innovative trend analysis for monthly, seasonal, and annual rainfall

high rainfall (>600mm) values fall below the 1:1 line indicating the presence of decreasing trend. For September, the low rainfall values (50mm to 150mm) fall near the 1:1 line, showing the absence of trend, whereas the medium (150mm to 300mm) and high (greater than 300mm) rainfall values fall above the 1:1 line, showing the presence of an increasing trend. For the seasonal time period, all the rainfall values fall below the 1:1 line, indicating a decreasing trend. In the case of annual rainfall, no trend is observed.

The uniform result of a statistically significant decreasing trend across all the methods is observed for June and seasonal rainfall. For July, the MK and SS tests show an insignificant trend, whereas MMK and ITA have detected a significant decreasing trend. For August, the MK, SS, and MMK tests show an insignificant trend, whereas ITA has found a decreasing trend for low values, no trend for medium values, and an increasing trend for higher rainfall values. For September, the MK and SS tests show an insignificant trend, the MMK test shows an increasing trend, whereas the ITA method shows no trend for small values and an increasing trend for the medium and high values of rainfall. The uniform result of no trend is observed for annual rainfall across all the tests.

The results of all the methods agree for June, seasonal and annual rainfall across all the methods. For July and September, the MK and SS tests failed to detect the trend, but both MMK and ITA successfully detected it. For August, the MK, SS, and MMK could not detect the trend that the ITA method successfully did. Thus, the ITA method outperforms over MK, SS, and MMK methods. The conclusions from the study may help the administration to take appropriate actions for water resource management.

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REFERENCES

Adarsh, S. and Janga Reddy, M. (2015). Trend analysis of rainfall in four meteorological subdivisions of southern India using nonparametric methods and discrete wavelet transforms. *Intern. J. Climatol.*, 35(6): 1107-1124. https://doi.org/10.1002/joc.4042

Al-Lami, A. M., Al-Timimi, Y. K. and Al-Salihi, A. M. (2024). Innovative trend analysis of annual rainfall in Iraq during 1980-2021. *J. Agrometeorol.,* 26(2): 196-203. https://doi.org/10.54386/jam.v26i2.2561

Ghanim, A. A. J., Anjum, M. N., Rasool, G., Saifullah, Irfan, M., Rahman, S., Mursal, S. N. F. and Niazi, U. M. (2023). Assessing spatiotemporal trends of total and extreme precipitation in a subtropical highland region: A climate perspective. *PLOS ONE*, 18(8): e0289570. https://doi.org/10.1371/journal.pone.0289570

Hamed, K. H. and Ramachandra Rao, A. (1998). A modified Mann-Kendall trend test for autocorrelated data. *J. Hydrol.*, 204(1-4): 182-196. https://doi.org/10.1016/S0022-1694(97)00125-X

Kendall, M. G. 1975 (Ed.). (1975). *Rank Correlation Methods*. Charles Griffin, London.

Nikhil Raj, P. P. and Azeez, P. A. (2012). Trend analysis of rainfall in Bharathapuzha River basin, Kerala, India. *Intern. J. Climatol.*, 32(4): 533-539. https://doi.org/10.1002/joc.2283

Pattanaik, D. R., and Bushair, M. T. (2024). Objective method of predicting monsoon onset over Kerala in medium and extended range time scale using Numerical Weather Prediction models. *Discover Appl. Sci.,* 6(7): 368. https://doi.org/10.1007/s42452-024-05909-y

Pradhan, M., Rao, A. S., Srivastava, A., Dakate, A., Salunke, K. and Shameera, K. S. (2017). Prediction of Indian Summer-Monsoon Onset Variability: A Season in Advance. *Sci. Reports,* 7(1):14229. https://doi.org/10.1038/s41598-017-12594-y

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. *J. American Stat. Assoc.,* 63(324): 1379-1389. https://doi.org/10.1080/01621459.1968.10480934

Şen, Z. (2012). Innovative Trend Analysis Methodology. *J. Hydrol. Engg.,* 17(9): 1042-1046. https://doi.org/10.1061/(ASCE)HE.1943-5584.0000556

Shankar, A. and Sharma, M. R. (2025). Rainfall variability and trends in different agroclimatic zones of Bihar, India. *J. Agrometeorol.,* 27(1): 100-103. https://doi.org/10.54386/jam.v27i1.2686