

Rainfall trend analysis using the Mann-Kendall test with pyMannKendall: a case study of Jeli, Kelantan

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Abstract. Trend analysis was widely used as a tool to detect changes in climatic and hydrological time series data such as rainfall. Therefore, this study aims to analyse the rainfall trends in Jeli, Kelantan from 2009 to 2020. Simple linear regression was used to impute missing data in all rainfall stations. The rainfall trends in time series were tested using the Mann-Kendall test and Sens' slope methods. This analysis was analysed using Python with pyMannKendall package. Kg. Jeli exhibited a statistically significant decreasing trend in rainfall, with a Kendall's Tau of -0.1412 and a Sen's slope of -0.0272 (p-value = 0.0121). However, no statistically significant rainfall trends were observed in the other three rainfall stations: Ldg. Kuala Balah, Kg. Gemang Bahru, and Kg. Ayer Lanas during the study period. Generally, this study concludes that the flood event was caused by high rainfall intensity.

1 Introduction

Over the past century, the global climate has experienced substantial changes, leading to various challenges, particularly in accurately identifying and quantifying rainfall trends [1]. Rainfall patterns are a crucial component of the hydrological cycle and play a significant role in water resource management, agricultural planning, and flood prevention [2]. In regions like Jeli in Kelantan, understanding these patterns is vital due to the area's vulnerability to extreme weather events, such as floods and droughts.

Trends of rainfall data provide a comprehensive view of how rainfall varies temporally. This study analyses the rainfall trends in Jeli, Kelantan from 2009 to 2020. The present study intends to identify trends and patterns within the rainfall data using the Mann-Kendall test and Sens' slope methods. These statistical tools are well-regarded for their robustness in

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detecting climatic and hydrological time series data trends. Through this analysis, we hope to contribute valuable insights that can aid in developing more effective climate resilience strategies and enhance the region's preparedness for future climatic changes.

Trend analysis is a widely used tool in climatology and hydrology for detecting changes in time series data, such as rainfall [3]. Numerous studies have utilised the Mann-Kendall test and Sens' slope methods to assess rainfall trends across different regions, demonstrating their effectiveness and reliability.

Rainfall trends have been extensively studied in various regions, revealing significant insights. Research in East Guji, Turkey, Kutch district in India, and the Manyame River catchment in Zimbabwe highlight the importance of analysing rainfall distribution over time and space such as to assess the recurrence of floods and to prepare contingency plans [4-7]. These studies showcase diverse trends, including increasing annual rainfall in highlands and lowlands, intensified extreme rainfall events attributed to convective rainfall, and varying trends in different rainfall regimes. Additionally, the research emphasizes the need for adaptive water resource management strategies to mitigate the impacts of changing rainfall patterns, such as floods and droughts. By utilizing advanced statistical analyses like the Mann-Kendall test and Sen's slope estimator, these studies provide valuable insights into the evolving spatiotemporal trends of rainfall, which are crucial for effective water resource planning and allocation.

Based on multiple research studies, analysis of rainfall trends in Kelantan, Malaysia reveals varying patterns over time and space. Studies in the Kelantan River Basin indicate increasing and decreasing trends in rainfall, with the northern region increasing while the southwest region experiences a decreasing trend [8]. Additionally, a regional assessment of extreme precipitation in the Kelantan River Basin from 1985 to 2014 highlights increasing trends in most precipitation extreme indices, particularly in the southwestern and northern regions, with exceptions in consecutive dry and wet days [9].

The motivation for this study stems from the need to address the challenges posed by climate variability in Jeli, Kelantan. By conducting a detailed rainfall trend analysis, we aim to identify significant trends and provide insights that inform flood management practices. Additionally, this study seeks to contribute to the broader body of knowledge on climate variability in tropical regions. Localized studies, such as this one, are crucial for understanding global climate patterns and their regional manifestations, thereby aiding in formulating more targeted and effective climate resilience measures.

2 Methodology

2.1 Study Area

In this current study, a rainfall trends analysis of four rain-gauged stations in the Jeli district of Kelantan has been conducted. The climate is generally warm and humid throughout the year, with low temperatures averaging between 21 and 32 degrees Celsius daily. According to the government's findings in recent years, the district of Jeli in Kelantan has been identified as particularly vulnerable to flooding, which is why it was chosen.

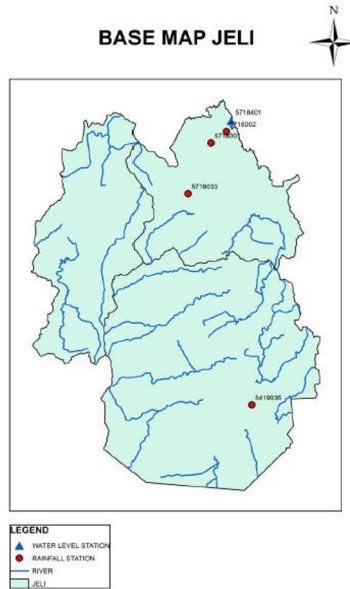


Fig.1. Location of the study area and rainfall stations.

2.2 Data collection

This study employs 4 rainfall stations from 2009 to 2020 obtained from Department of Irrigation and Drainage (DID): Ldg. Kuala Balah, Kg. Gemang Bahru, Kg. Jeli, and Kg. Ayer Lanas (Table 1). The present study intends to provide a trend analysis of the behaviour of rainfall data in Jeli, Kelantan, within the study period.

Table 1. Summary of the dataset used in the present study.

Station name	Latitude	Longitude	Percentage of missing data (%)	Period
Ldg. Kuala Balah	5.450000	101.913890	41.80	2009 - 2020
Kg. Gemang Bahru	5.761110	101.866670	40.61	
Kg. Jeli	5.700000	101.833300	41.68	
Kg. Ayer Lanas	5.784781	101.889731	39.93	

2.3 Linear interpolation

Monthly rainfall data were interpolated using simple linear regression to create a continuous time series to address the high percentage of missing data in the initial dataset. This approach facilitated a more comprehensive analysis of rainfall trends.

2.4 Statistical and Mann-Kendall Trend Analysis

In the present study, rainfall trend analysis was done using a non-parametric test, the Mann-Kendall test. This statistical method is used to study the spatial variation and temporal trends of hydroclimatic series. Mann-Kendall test is preferred when various stations are tested in a single study. In the present study, the descriptive analysis, plotting graph, and Mann-Kendall test are performed using Python. Python is one of the widely used tools for data analysis. Python is the foundation for developing numerous data analysis and research tools. Notably, pyMannKendall, a non-parametric Mann-Kendall trend analysis package, is exclusively implemented in pure Python. This package encompasses many Mann-Kendall tests, facilitating researchers' ability to ascertain Mann-Kendall trends within the Python environment [10].

3 Result and Discussion

The analysis of rainfall trends in Jeli, Kelantan, covering the period from 2009 to 2020, offers valuable insights into the region's climatic behavior. This study utilized the Mann-Kendall test and Sen's slope methods to analyse data from four rain-gauged stations: Ldg. Kuala Balah, Kg. Gemang Bahru, Kg. Jeli, and Kg. Ayer Lanas. The maximum recorded rainfall during the study period for these stations was 293.5 mm, 248.2 mm, 243.4 mm, and 283.7 mm, respectively (Table 2).

Table 2. Summary statistics of four rainfall stations.

Station	Mean \pm SD	Min.	Max.	Total rainfall
Ldg. Kuala Balah	7.53 \pm 16.65	0	293.5	33009.1
Kg. Gemang Bahru	13.53 \pm 20.67	0	248.3	41299.6
Kg. Jeli	12.59 \pm 19.67	0	243.4	40036.7
Kg. Ayer Lanas	13.54 \pm 22.48	0	283.7	43280.6

Fig. 2 and 3 illustrate the monthly rainfall data for the four stations before and after linear interpolation to impute missing data, respectively. Various approaches have been proposed to enhance the accuracy and efficiency of linear regression interpolation. Oravkin and Rebeschini introduced an optimal response-linear interpolation method for linear regression that achieves optimality by considering data characteristics and signal-to-noise ratios [11]. Zhu et al. proposed a method called CAIDWR by integrating clustering algorithms and weighted linear regression to improve the Inverse Distance Weighting (IDW) spatial interpolation algorithm [12].



Fig. 2. Monthly rainfall data with missing values.

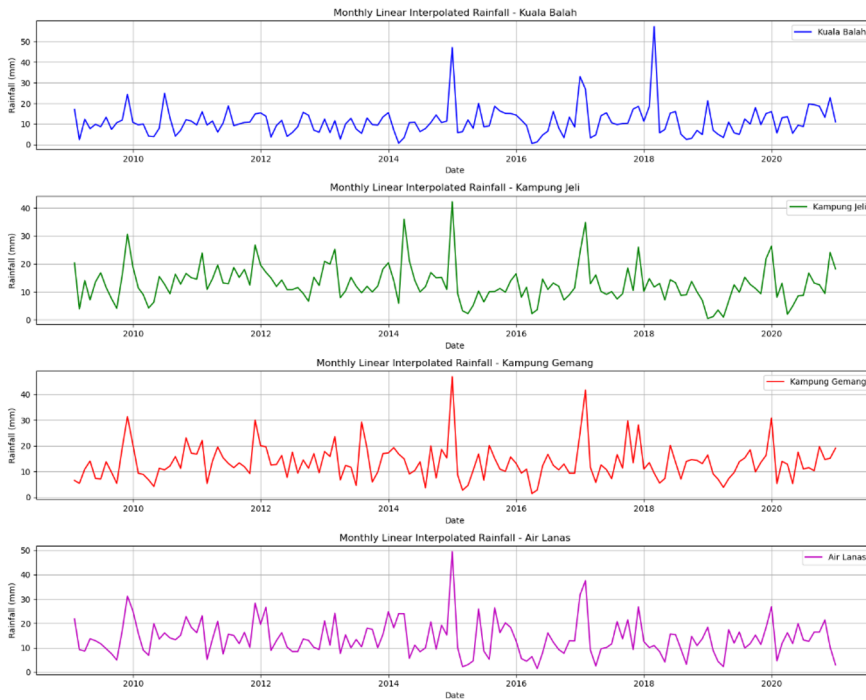


Fig. 3. Monthly rainfall data for four Jeli stations after linearly interpolating to impute missing data.

The findings of Mann-Kendall trend analysis revealed that Ldg. Kuala Balah, Kg. Gemang Bahru, and Kg. Ayer Lanas have no significant in rainfall trends ($p > 0.05$). However, Kg. Jeli exhibited a statistically significant decreasing trend in rainfall, with a Kendall's Tau of -0.1412 and a Sen's slope of -0.0272 ($p\text{-value} = 0.0121$). This declining trend in Kg. Jeli underscores potential concerns for water resource management and agricultural planning in

the area, highlighting the necessity for continuous monitoring and adaptive strategies to mitigate the impacts of changing rainfall patterns.

The absence of significant trends in three stations suggests that the overall rainfall patterns in Jeli, Kelantan, have remained relatively stable over the study period. However, there was a significant decrease in rainfall at Kg. Jeli could have localised implications, particularly for sectors dependent on consistent water availability, such as agriculture.

Table 3. Summary of Mann-Kendall result.

Station	Kendall's Tau	p-value	Sen's slope
Ldg. Kuala Balah	0.0521	0.3554	0.0113
Kg. Gemang Bahru	0.0093	0.8697	0.0014
Kg. Jeli	-0.1412	0.0121	-0.0272
Kg. Ayer Lanas	-0.0538	0.3395	-0.0538

4 Conclusion

In conclusion, while most Jeli, Kelantan, does not exhibit significant changes in rainfall trends, the notable decreasing trends at Kg. Jeli highlights the need for proactive measures to manage water resources effectively. To enhance the reliability of rainfall datasets and improve the robustness of future studies, it is recommended that advanced interpolation methods be employed. Techniques such as kriging, spline interpolation, and machine learning-based approaches can offer more accurate estimations of missing data, thus increasing the reliability and comprehensiveness of the rainfall data. Implementing these advanced methods will strengthen the analysis, providing deeper insights into climatic trends and supporting more effective water resource management and agricultural planning.

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