Advances and Applications in Mathematical Sciences
Volume 21, Issue 6, April 2022, Pages 3419-3429

ANALYSIS OF TREND AND MAGNITUDE USING MANN-KENDALL AND SEN'S SLOPE TEST IN 115 YEARS ANNUAL RAINFALL DATA OF SOUTH INDIA

MUNAVER JAMAN BASHEER AHAMED[1], C. RAVICHANDRAN[1] and ABDEL AZIM MOHAMED EBRAHEEM[2]

[1]PG and Research
Department of Environmental Sciences
Bishop Heber College
Affiliated to Bharathidasan University
Tiruchirappalli-620017, India
E-mail: jamanphd@gmail.com

[2]Emeritus Professor
Assiut University, Egypt

Abstract

Global temperatures are expected to rise over 2°C if urgent mitigative actions are not taken. Extreme weather events are becoming more frequent due to climate change. Rainfall is a major phenomenon of the atmosphere and a vital climatic factor that can indicate climate changes. Rainfall reduction will prompt greater extraction of groundwater and increases temperature level. Hence, it is the exact time to analyze the trends and corresponding magnitude in historical rainfall data. It may help in developing action plans and adaptation strategies to combat the consequences of altered rainfall patterns. In this study, 115 years of monthly rainfall data are used in the Mann Kendall trend detection test and Sen's slope estimator test to analyze the trends and magnitudes of eight regions in South India. These two tests were run in three software models namely eWater Toolkit, Minitab and Auto Trend analyzer. All three models' results are identical to one another. The results support the environmentalists and corresponding government sectors to implement the adaptation measures.

2020 Mathematics Subject Classification: 62P12.

Keywords: Climate change, Statistical analysis, Mann Kendal trend, Sen's slope estimator, South India.

Received March 24, 2022; Accepted April 17, 2022

1. Introduction

Myriad of human activities have resulted in many environmental changes including global warming and climate change. Rainfall is an important meteorological parameter which has direct influence on water resources and water availability, which in turn affects urban water supply and industrial, residential and agricultural water uses [1]. Hence prediction of rainfall and understanding trend analysis become necessary [2].

Population growth, urbanization, and industrialization during the last 30 years are some of the reasons for warming trend in temperature, which may lead to increasing aridity during summer and spring seasons and will put more pressure on surface and ground water resources [3]. Worldwide climatologists are investigating to find a possible relation of climate change with anthropogenic behavior by studying trends in different climatic parameters [4].

Statistical analysis of hydrological time series plays a vital role in water resources studies [5]. Analysis of precipitation trends is an important for water resources planning and management [6]. The variation in rainfall is essential from agricultural point of view for precise estimation of supplemental water requirements so it is required to calculate the rainfall variability on both annual and seasonal basis [1]. Shortage of water in the river in relation to rainfall change plays a pivotal role in water sharing [7]. The study of long-term precipitation record is critically important for a country whose food security and economy rely on the timely availability of water [8]. Therefore, awareness of spatial and temporal distribution and changing pattern of rainfall is essential and a vital requirement for future planning and management of water resources [9].

For the above situations all over the world, it is necessary to understand the rainfall time series and the probable trends. These will help to estimate the future water availability and amount of water requirement. In this study, the analysis of long-term rainfall data of South India is considered and the corresponding mean annual and mean seasonal patterns are calculated.

2. Data Collection

In this present study, monthly rainfall data for the time 1901 to 2015 was collected through Open Government Data (OGD) Platform India through the online link http://data.gov.in. The annual Figure 1 and seasonal Figure 2 (Autumn, Spring, Summer and Winter) precipitation are calculated by statistical test from the monthly data for all regions and for the same time period.

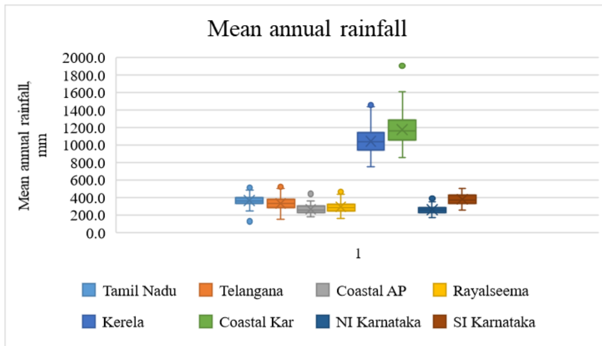
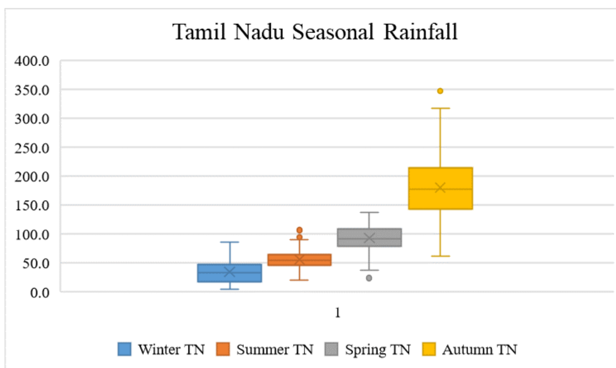
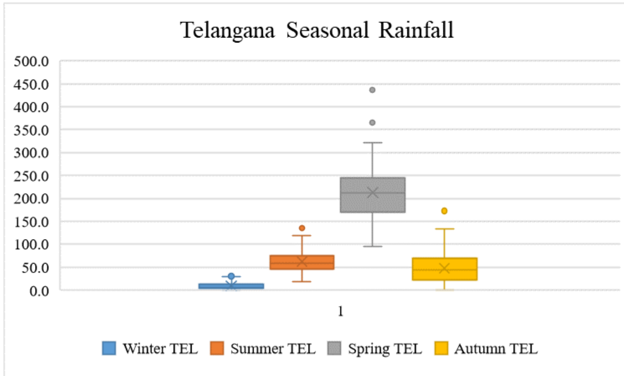
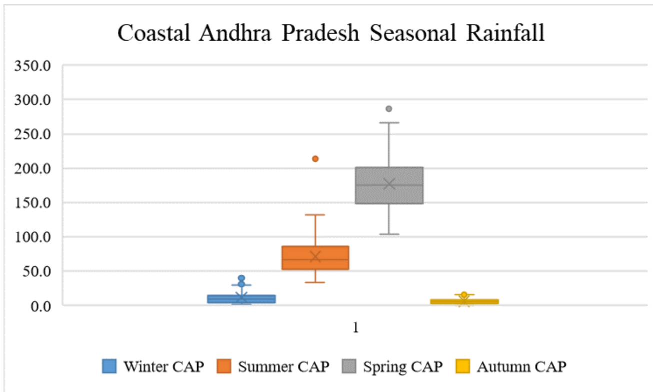
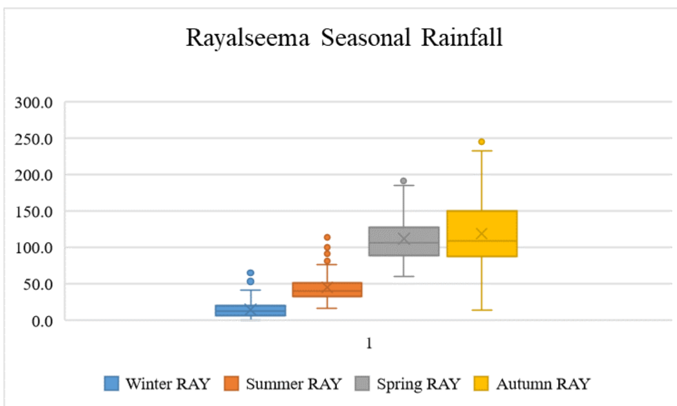


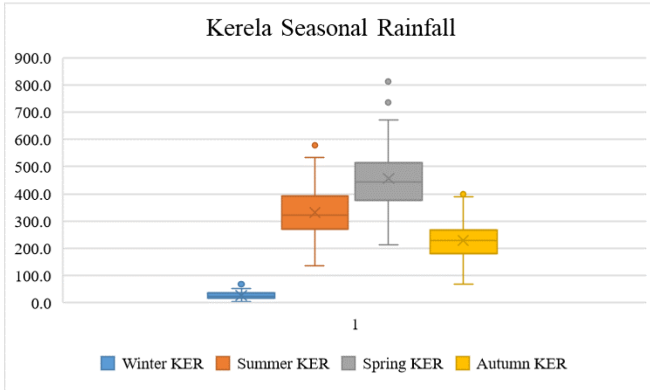
Figure 1. Mean annual rainfall for all regions.

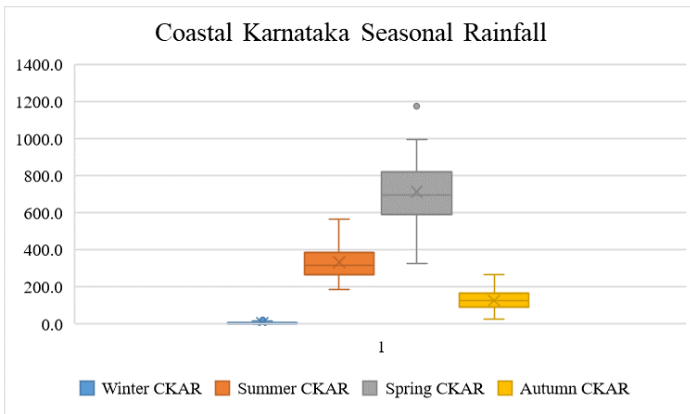


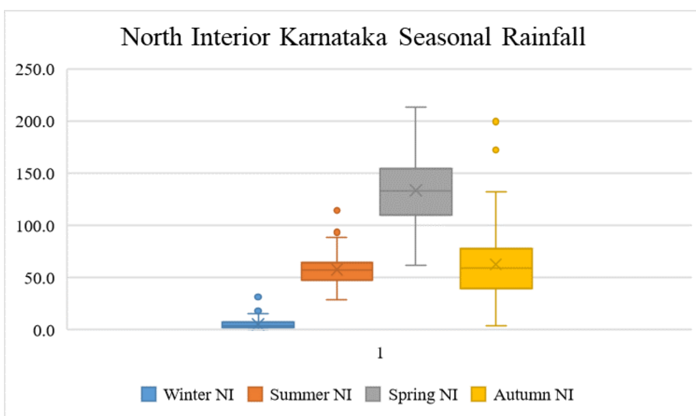

Telangana Seasonal Rainfall
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
1
Winter TEL
Summer TEL
Spring TEL
Autumn TEL


Coastal Andhra Pradesh Seasonal Rainfall
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
1
Winter CAP
Summer CAP
Spring CAP
Autumn CAP


Rayalseema Seasonal Rainfall
300.0
250.0
200.0
150.0
100.0
50.0
0.0
1
Winter RAY
Summer RAY
Spring RAY
Autumn RAY


Kerela Seasonal Rainfall
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
1
Winter KER
Summer KER
Spring KER
Autumn KER


Coastal Karnataka Seasonal Rainfall
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
1
Winter CKAR
Summer CKAR
Spring CKAR
Autumn CKAR


North Interior Karnataka Seasonal Rainfall
250.0
200.0
150.0
100.0
50.0
0.0
1
Winter NI
Summer NI
Spring NI
Autumn NI

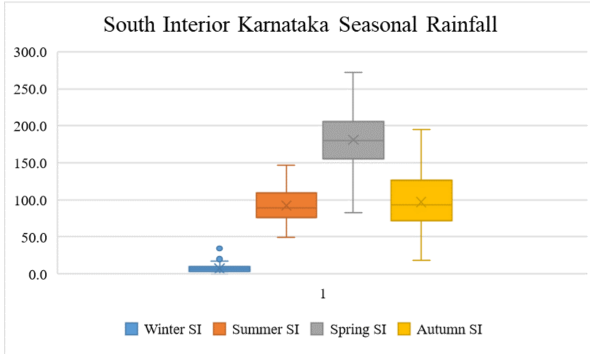


Figure 2. Mean seasonal rainfall for all regions.

3. Results and Discussion

In this paper, two types of statistical analysis namely Mann-Kendall test and Sen's slope test were used for trend detection and slope estimator in both mean annual rainfall and mean seasonal rainfall data. [10] Presented a non-parametric test for randomness against time, which constitutes a particular application of Kendall's test for correlation commonly known as the 'Mann-Kendall' or the 'Kendall *t* test' [11]. A positive value of Z indicates an upward trend and its negative value a downward trend. The statistic Z has a normal distribution. To test for either an upward or downward monotone trend (a two-tailed test) at α level of significance, H_0 is rejected if the absolute value of Z is greater than $Z_{1-\alpha/2}$, where $Z_{1-\alpha/2}$ is obtained from the standard normal cumulative distribution tables. The Z values were tested at 0.05 level of significance. To estimate the true slope of an existing trend (as change per year) the Sen's nonparametric method is used. The Sen's method can be used in cases where the trend can be assumed to be linear.

The data of mean annual and seasonal rainfall is considered for this study and analyzed the values with three different software namely 1. eWater Toolkit 2. Minitab 3. Auto Trend analyzer. The generated results from the all three software are identical. The results of the mean annual and seasonal rainfall are represented in the Table.1. The significant changes at 90% resulting for the annual data of Telangana and spring season of Telangana. There are no any significant changes for any other regions for means annual and seasonal data under significance changes at 90%.

Table 1. Mann Kendall test results for all study areas.

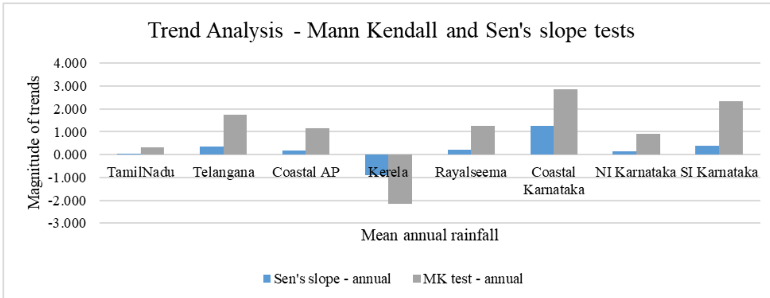
Data Period	Location	Result
Annual	Telangana	Significance changes at 90%
Autumn	All study areas	No significant changes
Spring	Telangana	Significance changes at 90%
Summer	All study areas	No significant changes
Winter	All study areas	No significant changes

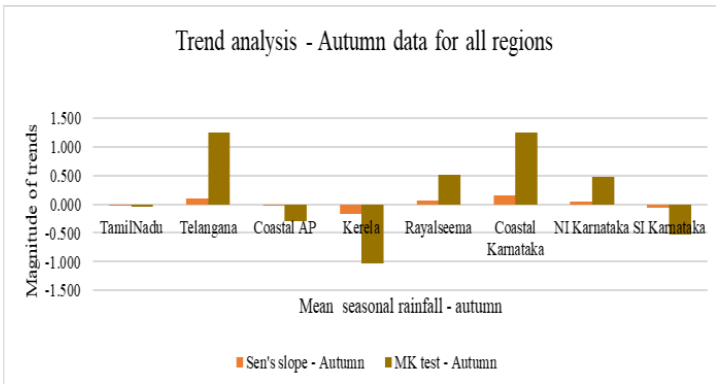
Sen's slope results show that the magnitude of the rainfall is more than average. In mean annual rainfall - only Kerala resulted negative magnitude, in autumn season – four of the eight regions resulted negative magnitude, in spring season, only Kerala resulted the negative magnitude, in summer season – Tamil Nadu and Kerala resulted negative magnitude and in winter season – five out of 8 regions are negative magnitude.

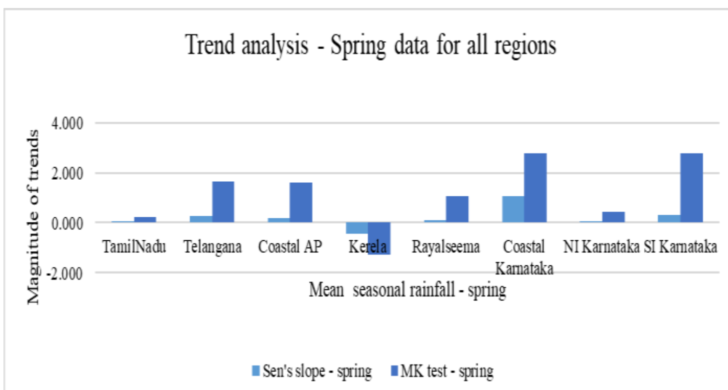
Table 2. Sen's slope test results for mean annual rainfall for all study areas.

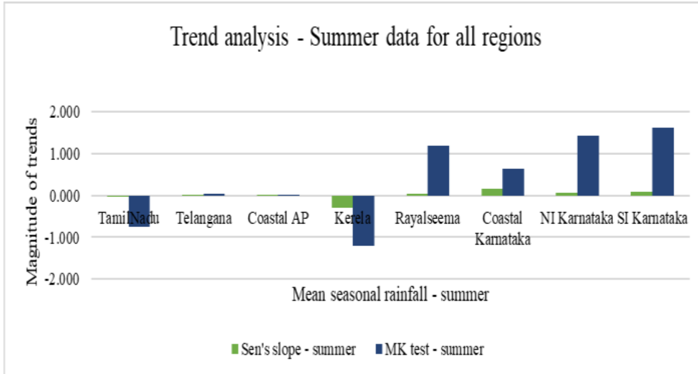
Study Area	Annual	Autumn	Spring	Summer	Winter
Tamil Nadu	0.046	-0.005	0.013	-0.034	-0.077
Telangana	0.364	0.099	0.287	0.001	0.008
Coastal AP	0.165	-0.003	0.17	0.001	-0.007
Kerala	-0.917	-0.176	-0.419	-0.298	-0.073
Rayalseema	0.209	0.066	0.096	0.044	0.003
Coastal Karnataka	1.274	0.154	1.077	0.149	0
NI Karnataka	0.136	0.045	0.043	0.059	-0.007
SI Karnataka	0.397	-0.057	0.309	0.091	-0.002

The results of both MK and Sen's slope tests are represented in the bar type chart for mean annual data and seasonal rainfall data (autumn, spring, summer and winter).









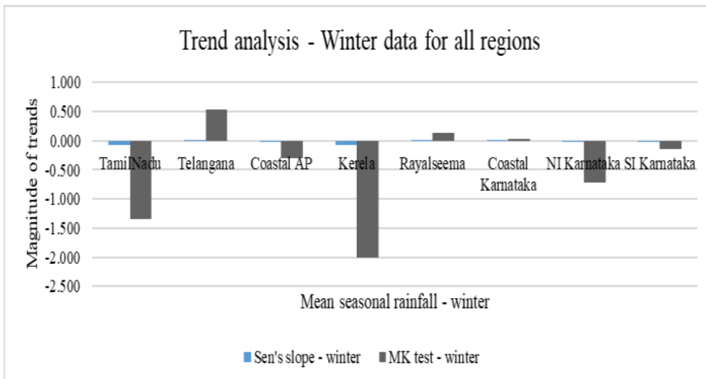


Figure 3. Mann Kendall and Sen’s slope test results for mean annual and seasonal rainfall for all study areas.

4. Conclusion

The trend analysis and magnitude estimator for the recent 115 years of annual data (1901 – 2015) are analyzed using MK trend and Sen’s slope tests. The results of the trend analysis show that Telangana having the significance level of 0.1. The magnitude of the study regions are analysed and resulted that more than half of the regions are negative magnitude value during Autumn and Winter seasons. Hence consider this as the evidence to immediately start the adaptation measures for South India.

5. Recommendation

Even though Tamil Nadu is not having any significant changes in the trend analysis, the following things are to be considered: Increase in population; Immigration of population; Increasing of construction works (which consumes 10% of water in industrial consumption); Decrease in agriculture; Sand mining of rivers, which results the level of penetration. Therefore, updation of trend analysis and its magnitude in precipitation series are important for policy makers, water resources management and agriculturists. Hereby recommending that the trend analysis is required to analysis every year from the updated rainfall data for each region.

References

[1] S. Gajbhiye, C. Meshram, R. Mirabbasi and S. K. Sharma, Trend analysis of rainfall time series for Sindh river basin in India, Theoretical and Applied Climatology, 125, 593-608 (2016). https://doi.org/10.1007/s00704-015-1529-4

[2] A. Kundu, S. Dwivedi and V. Chandra, Precipitation Trend Analysis over Eastern Region of India Using Cmip5 Based Climatic Models, ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XL-8, 1437-1442 (2014). https://doi.org/10.5194/isprsarchives-XL-8-1437-2014

[3] M. Zarenistanak, A. G. Dhorde and R. H. Kripalani, Trend analysis and change point detection of annual and seasonal precipitation and temperature series over southwest Iran, Journal of Earth System Science 123, 281-295 (2014). https://doi.org/10.1007/s12040-013-0395-7

[4] N. Mishra, D. Khare, R. Shukla and K. Kumar, Trend Analysis of Air Temperature Time Series by Mann Kendall Test - A Case Study of Upper Ganga Canal Command (1901-2002), British Journal of Applied Science and Technology, 4, 4066-4082 (2014). https://doi.org/10.9734/BJAST/2014/8650

[5] D. Machiwal and M. K. Jha, Comparative evaluation of statistical tests for time series analysis: application to hydrological time series / Evaluation comparative de tests statistiques pour l'analyse de séries temporelles: application à des séries temporelles hydrologiques, Hydrological Sciences Journal, 53 353-366 (2008). https://doi.org/10.1623/hysj.53.2.353

[6] M. Thenmozhi and S. V. Kottiswaran, Analysis of Rainfall Trend Using Mann-Kendall Test and The Sen's Slope Estimator in Udumalpet of Tirupur District in Tamil Nadu, International Journal of Agricultural Science and Research (IJASR) 6 (2016), 131-138.

[7] S. Bera, Trend Analysis of Rainfall in Ganga Basin, India during 1901-2000, American Journal of Climate Change, 06 116-131 (2017). https://doi.org/10.4236/ajcc.2017.61007

[8] S. Gajbhiye, C. Meshram, S. K. Singh, P. K. Srivastava and T. Islam, Precipitation trend

analysis of Sindh River basin, India, from 102-year record (1901-2002): Precipitation trend of Sindh River basin, Atmospheric Science Letters, 17, 71-77 (2016). https://doi.org/10.1002/asl.602

[9] P. Jagadeesh and C. Anupama, Statistical and trend analyses of rainfall: a case study of Bharathapuzha river basin, Kerala, India, ISH Journal of Hydraulic Engineering, 20 119-132 (2014). https://doi.org/10.1080/09715010.2013.843280

[10] H. B. Mann, Non parametric test against trend, Econometrica (1945), 245-259.

[11] M. G. Kendall, Rank Correlation Methods, New York, Hafner Press, (1962).