RAINFALL VARIABILITY AND TREND ASSESSMENT FOR RAINFED REGION OF RAMANATHAPURAM DISTRICT, TAMIL NADU, INDIA

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Abstract. Agriculture is the most vulnerable sector to climate change and weather anomalies. In rainfed ecosystems, rainfall amount and distribution are the deciding factors for crop planning. Rainfall variability and trend analysis help to minimize weather related risk and enhance the productivity by proper crop planning. The study on rainfall distribution and its trend was assessed in a rainfed area of Ramanathapuram district of Tamil Nadu, India by using Simple descriptive statistics along with non-parametric analysis of Men-Kendall analysis, Sen's slope estimator; innovative trend analysis and sequential Men-Kendall test were carried out to understand the quantity of rainfall and rainy-day variability for the period of 1982 to 2022. The results indicated that the mean annual rainfall is 716 mm and spread over 56 rainy days with 21 percent of coefficient of variation. Seasonal analysis indicated that, there was no significant trend was observed among the seasons, but NEM showed a significant increase in trend (p-value = 0.048) with a positive magnitude of 3.2 mm/ year of rainfall. An increasing trend in heavy rainfall events during the NEM season is evident with 92 percent.
Keywords: *climate, variability, rainfed, trend, extremes*

Introduction

Food security, nutritional security, and energy security are crucially dependent on the timely availability of adequate amounts of moisture and a conducive climate for agriculture and allied sectors. Climate change in the rainfed regions, particularly in the monsoon rainfall, would have a major impact on the country's agricultural production, water resources management, and overall economy (Piao et al., 2010). Currently, approximately 60% of the 142.2 million hectares of net cultivated area is rainfed (Sharma et al., 2010) and this accounts for 44% of the total food grain production (Rosegrant et al., 2002). Rainfall is a significant factor in determining the success of rainfed agriculture in a specific agro-ecological region. The growth and yield of crops are influenced by the quantity and distribution of rainfall received during a particular season. The onset, distribution, and cessation of seasonal rainfall fluctuate over the time series (Vengateswari et al., 2019), which is affecting agricultural operations and productivity (Pathak and Dodamani, 2020). Rainfall and rainy-day trends are crucial to understanding the variation of underlying patterns due to climate change (Naheed et al., 2013).

Tangney (2020) has reported that in the near future, climate change is likely to impact agriculture, increase the risk of hunger, and exacerbate water scarcity. Kumar and Jain (2010) reported that variations in rainfall distribution would impact the spatial and temporal distribution of runoff, soil moisture, and groundwater storage, ultimately

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altering the frequency of droughts and floods. The scope to improve agricultural productivity in a rainfed ecosystem is limited, as they suffer from a number of biophysical and socio-economic constraints especially low and erratic rainfall and poor productivity (Sharma and Patterson, 1999). Rainfall variability, especially deficit rainfall, increases the vulnerability of rain-fed agriculture (Ashok et al., 2018). The majority of the people are depending on agricultural activities for livelihood in rainfed ecosystem. The drought years and excess rainfall years resulted in low agricultural production and increased the indeptness of farmers, the poor farmers becoming the poorest (Mutekwa, 2009). About 90 percent of the farmers/ farms in the rainfed environment are found inefficient since their actual yields were lower than the optimal yields.

Ramanathapuram district of Tamil Nadu, agriculture is dependent on the seasonal rainfall pattern due to its predominant area under rainfed agriculture and facing severe water scarcity issues and drought prone due to erratic rainfall pattern and distribution. Seasonal rainfall is highly variable with unusual weather characteristics like varying intensity of rainfall and altered with wet and dry spells. The quantam of rainfall received during the season and its distribution is an important factor in deciding the quantam of water available for a selection of crops as well as varieties (Gabremichael et al., 2014). In addition, NEM seasonal rainfall helps to recharge the groundwater level, which is a critical factor for rainfed agriculture (Gowtham et al., 2020). The districts get benefits from North East Monsoon (NEM) rainfall by the contribution of 60 per cent of its annual rainfall. Delayed or insufficient rainfall can result in crop failure, leading to significant losses to farmers (Rockstrom et al., 2003). The common features of rainfed regions viz., uneven distribution of rainfall and low crop productivity are also features of the study area (Balaji et al., 2013). Inequality in rainfall distributions or monsoon failure associated with the absence or scarcity of water could adversely affect the crop at the germination stage and early growth stages of the crop.

The sowing window starts from standard week of 28 to standard week of 35. The sowing during 28th standard week used to cultivate medium and long duration varieties of paddy. whereas monsoon delays upto the standard week of 32-35, which delays the sowing of paddy and also encourages to go for short duration varieties. Sowing of landraces during drought periods in the Ramnad district was found higher, due to the character of high stress tolerant and assure with minimum yield (Selvaraj et al., 2009). Yield variation among the normal and erratic rainfall years also shows that yield variability is around 44 to 60 percent. The analysis was conducted to find out the suitable crop and variety, effective agronomic practices to achieve optimum yield, and also minimize the risk of crop failure.

Materials and Methods

Study area

The study was conducted by using the weather data of Ramanathapuram district, which is situated in the southern zone of Tamil Nadu, India at 9° 20’ N latitude and 78° 53’ E longitude and an elevation of 6 m above the mean sea level with 237 km coastal length (*Figure 1*). The total cropped area of the district is 2,00,899 hectares. The area under irrigated agriculture is 32 per cent and 68 per cent is under rainfed agriculture, also considered as a rainfed district of Tamil Nadu.

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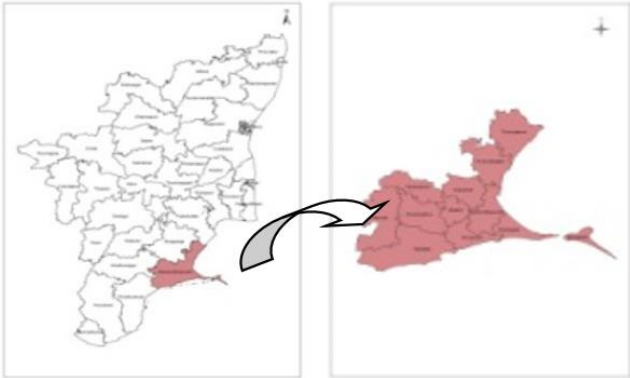

Figure 1. *Study area*

Data and analysis

The daily rainfall at 25 km resolution gridded data for the period of 40 years (1982-2022) has been collected from the India Meteorological Department and utilized for analysis. In ArcGIS, interpolation techniques were employed to improve the accuracy and spatial distribution of the rainfall data over district. The data were checked on quality aspects and the time series of seasonal scale were prepared from the daily rainfall data using R software. Different statistical characteristics like mean, standard deviation, and coefficient of variation (CV) were calculated for different seasons for a period of 40 years. The CV is expressed as a percentage and is used to determine the dependability of rainfall. The magnitude of the trend in a time series was determined by regression analysis (parametric test). The linear trend value represented by the slope of the simple least-squares regression line provided the rate of rise/fall in the variable. A rainy day was calculated based on the day receiving more than 2.5 mm of rainfall for each season. Trends in the frequency of heavy rainfall events (> 60 mm) were examined on annual and season wise. The correlogram tool was used to explore the inter-dependency of the data sets and insights into the dynamics of time series data.

Non-parametric analysis such as Men-Kendall analysis (MK) and Sen’s slope estimator (SS) were used to detect significant temporal trends in the meteorological variables. The Men-Kendall analysis was used to measure the trend in the data; it is defined as the sum of the number of positive differences minus and the number of negative differences between consecutive sample results (Vengateswari et al., 2019). The standard normal variable Z is used to identify the direction of the trend and its significance. Positive Z values are a sign of an increasing trend while negative values show a decreasing trend.

The change per unit time within the time series was estimated by the nonparametric Sen’s slope estimator, the Sen’s slope estimator works based on calculating the median of the slopes between all pairs of points in the time series. Innovative trend analysis (ITA) was also used for aiding the results of trend analyses (Dharani et al., 2022). Sequential Men-Kendall analysis (SQMK) was used for detecting the beginning and end of trends by breaking the time series into smaller segments to detect the trends in the data. The results were combined and the overall assessment of the trend in the data series was estimated.

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Results and Discussion

The analysis of the results shows that the mean annual rainfall of Ramanathapuram district was 716 mm with the lowest rainfall 412 mm and the highest 1047 mm in 1991 and 2021, respectively. Which was received over a period of 56 rainy days with a standard deviation of 154 mm and the coefficient of variation was 21 per cent. The annual rainfall analysis indicated that the annual rainfall was considered dependable (level 25%). The seasonal rainfall analysis showed that the mean rainfall of winter (January- February), summer (March-May), South West Monsoon (SWM, June – September) and NEM (October – December) were 48 mm, 133 mm, 55 mm and 478 mm, respectively, with CV value of winter (63%) and SWM (50%) recorded higher CV value than the threshold level of 50 per cent and the rainfall was much dependable in NEM was 28 per cent and summer was 45 per cent (*Table 1*).

Table 1. *Variation in Annual and Seasonal rainfall in Ramanathapuram district*

Season	Mean rainfall (mm)	Standard deviation	Coefficient of variation (%)	Maximum (mm)	Minimum (mm)
Winter	48	31	63	254	10
Summer	133	60	45	305	41
SWM	55	27	50	123	11
NEM	478	136	28	787	191
Annual	716	154	21	1047	412

The result of Correlogram (*Figure 2*) shows that the different time series of rainfall data were independent, therefore, the Men-Kendall analysis is applied to the corresponding time series. The innovative trend analysis for annual rainfall showed that monotonous increasing trend in annual rainfall (*Figure 3*), with a positive magnitude of 4.3 mm per year of rainfall estimated from the Sen's slope estimator (*Table 2*). The results of Men-Kendall analysis showed that a significant positive trend (p-value = 0.023) in annual rainfall over a period of 40 years (1982-2022) in Ramanathapuram district and Sequential Men-Kendall analysis indicated that the trend began during 1996 and continues still.

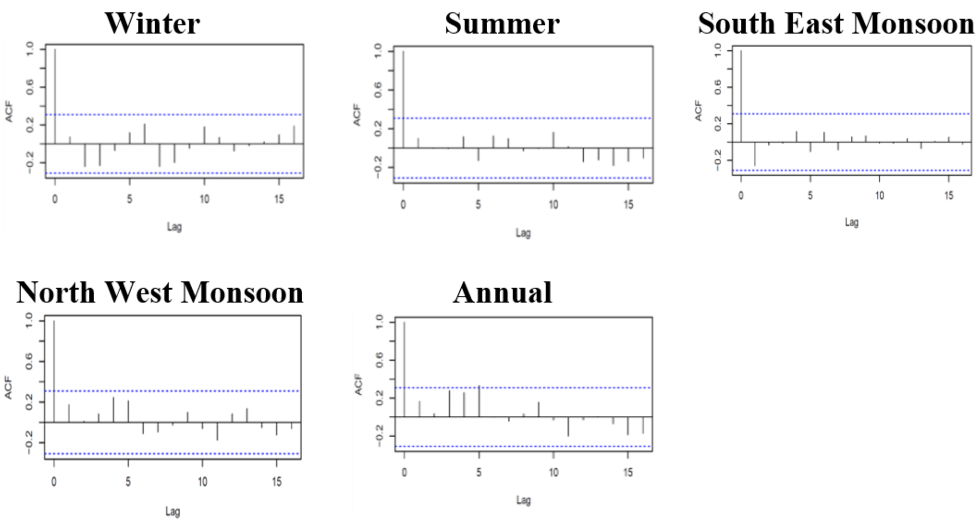

Figure 2. *Correlogram of annual and seasonal rainfall time series*

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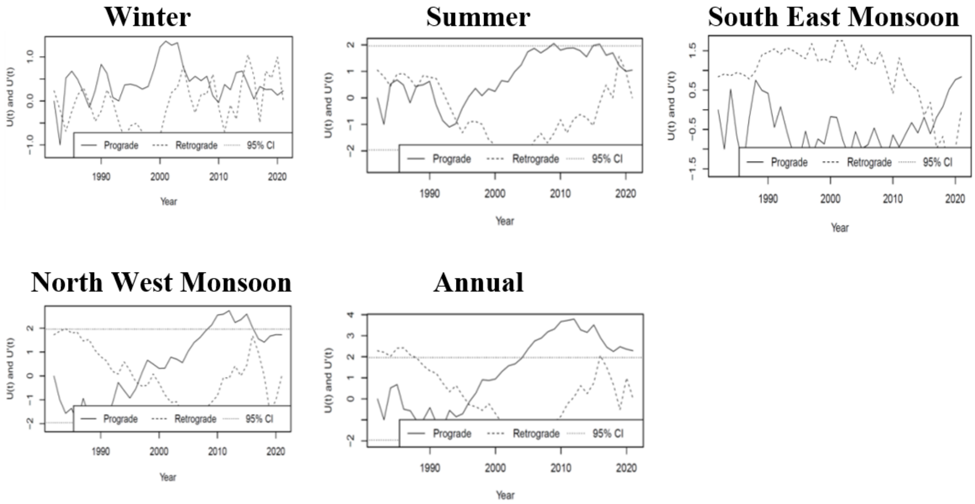

Figure 3. *SQMK test for rainfall time series with Prograde U(t) and Retrograde U'(t)*

Table 2. *SS, MK, ITA, and SQMK test results for annual and seasonal rainfall trend analysis in Ramanathapuram district*

Season	SS test	MK test (z value)	ITA	SQMK Test A trend begins and ends
Winter	0.05	0.22	NM (-)ve	1984-1987, 1989-2004, 2005-2009, 2010-2015, 2017-2018
Summer	0.73	1.03	NM (+)ve	1984-1985, 1988-1989, 1995-2019, 2020- Still
SWM	0.23	0.82	NM (+)ve	2016- Still
NEM	3.21	1.71*	M (+)ve	1997- Still
Annual	4.32	2.27*	M (+)ve	1996- Still

* Trend at 5% Significance level; NM =Non monotonous, M = Monotonous

The seasonal trend analysis showed that the increasing trend was observed in all seasons, which was supported by Sen's slope estimator (*Table 2*). The ITA test resulted that a monotonous increasing trend was observed in annual and NEM, whereas during summer and SWM there was a non-monotonous increasing trend, but a non-monotonous decreasing trend was observed during winter. Gadedjisso Tossou et al. (2021) found that there was an uneven distribution of rainfall was observed even the quantum of rainfall increased within the season. However, there was no significant trend was observed through the Men-Kendall test for winter, summer, and SWM seasons, but NEM showed a significant increasing trend (p-value = 0.048) with a positive magnitude of 3.2 mm/ year of rainfall estimated from the Sen's slope test. SQMK resulted in more significant variability in the beginning and ending of the trend in winter and summer rainfall and for SWM, the trend began in 2016 and continues Likewise for annual and NEM trends beginning in 1997 and 1996, still continuing (*Figure 4*).

The mean annual rainy day of Ramanathapuram district from 1982- 2022 was 56 days, with a highest of 86 rainy days during the year 2005 and a lowest of 31 days during 1983, respectively. The trend analysis showed that there was an increasing trend in annual rainy days with a linear equation of Y= 0.699X + 42 with the R^2 value of 0.35 (*Table. 3*). The seasonal rainy days analysis showed that NEM is predominant with 28 rainy days followed by summer with 15 rainy days, whereas SWM had 8 rainy days and winter 5

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rainy days. The total number of rainy days was slightly decreasing in winter, whereas increasing in summer and SWM, but the changes were not statistically significant. During the Northeast Monsoon, there was an increasing trend in mean rainy days with an R^2 value of 0.4. The trend analysis indicates that the annual and Northeast Monsoon, average rainfall and number of rainy days increase. This suggests that over the years, there has been an increase in the amount of rainfall received during these seasons due to increase in cyclone frequency in the Bay of Bengal during November and the steady warming of the Indian Ocean may be the causes behind the rainfall increase (Prakash et al., 2013).

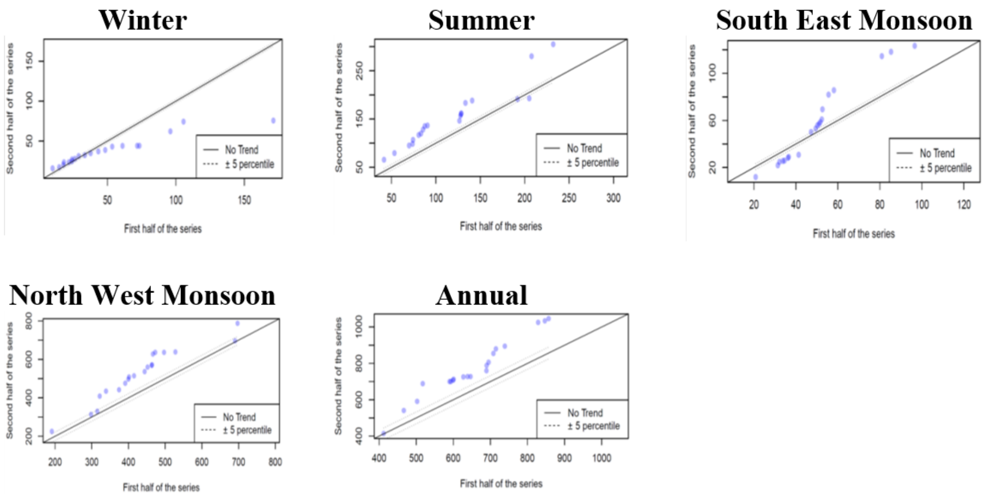

Figure 4. *ITA plot for rainfall time series*

Table 3. *Linear regression results for annual and seasonal rainy day trend analysis in Ramanathapuram district*

Season	Rainy days	Linear equation	R^2
Winter	5	Y=-0.009X+4.857	0.002
Summer	15	Y=0.197X+11.41	0.160
SWM	8	Y=0.018X+7.148	0.003
NEM	28	Y=0.501X+18.36	0.44
Annual	56	Y=0.699X+42	0.35

Heavy rainfall events in terms of frequency of occurrence show that there was an increasing trend with no significance. To examine the variability and long-term trends of extreme events, the time series shows year to year considerable fluctuations, as well as substantial variations over the study period (Shekhar et al., 2017). It's interesting to note that during the NEM, heavy rainfall events contribute to about 92 percent (*Figure 5*). The changes in the heavy rainfall patterns pose a serious threat to agricultural crop production (Praveen et al., 2019). During summer, heavy rainfall events accounted for 6 percent, while during winter it was 2 percent. Southwest Monsoon did not contribute to heavy rainfall events.

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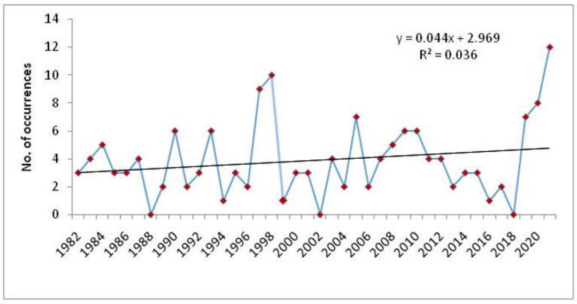
Annual occurrence of heavy rainfall events



Season wise Percentage share of heavy rainfall events

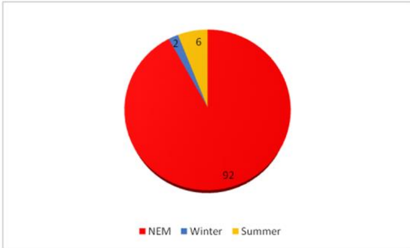


Figure 5. *occurrence of heavy rainfall events for annual and seasonal time series*

Conclusion

Quantum of rainfall and rainy days are the important weather parameters decides the production and productivity of rainfed agriculture. Understanding the trends of rainfall is indispensable to suggest crop planning of rainfed regions. Trend analysis of Ramanathapuram district showed statistically significant increasing trends for annual and Northeast monsoon rainfall. Winter and summer seasons, more variability was observed in rainfall quantity whereas during SWM, the increasing trend began in 2016 and still continues. The rainy-day trend analysis also increases in annual and North East Monsoon. Heavy rainfall events in terms of frequency of occurrence show that there was an increasing trend during the NEM, was contributes about 92 percent. The observed trend suggests the enhanced risks associated with rainfall over the region in the coming decades.

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