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RESEARCH PAPER

Weather analysis through Mann-Kendall test and other applications

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Abstract: The present study analyzed changing trends of rainfall and temperature of the Raichur region which belongs to the North-Eastern dry zone of Karnataka, India. Normal climatic variables including rainfall, rainy days and temperature recorded over 35 years were analyzed. The data has been processed to find out the monthly variability which is part of non-parametric Mann-Kendall test. Further, it has been used together with Sen's slope estimator for the determination of trend and slope magnitude for time series data. Rainfall data analysis has shown a decreasing trend (732 to 622 mm) in all the seasons except summer with a coefficient of variation as 29%. Mean monthly maximum temperature was found to have a decreasing trend (34.3 to 34.0^{0}C) over years whereas, the monthly minimum temperature was found to have an increasing trend (20.5 to 21.1^{0}C). The annual temperature trend has indicated that there was no significant difference during the period of observation except forthe post-monsoon season. Number of rainy days was reduced (41.9 to 36.3) in all the seasons due to spatio-temporal variability. Results from this study would serve as a guide for future yield predictions, crop simulation models, crop planning, and agriculture practices in the region.

Key words: Mann-Kendall test, Rainfall, Temperature, Trend analysis

Introduction

Monsoon onset over Kerala decides the main rainy season in the Indian subcontinent. Quantitative analysis and distribution of rainfall and temperature is required for various purposes of crop production like irrigation scheduling, flood forecasting, climate change studies, water balance computations, soil moisture modeling etc. One of the most significant consequences of climate change is increased greenhouse gases (GHGs) that result into an uncertainty in rainfall distribution and temperature variation. In India rainfall plays a major role in determining the economy of the country and knowledge regarding its trends helps to economic development, disaster management, hydrological planning.

Mann–Kendall's non-parametric trend test (Kendall, 1975) is widely used (Oguntunde *et al.*, 2011) to detect significant trends in the time series data. It is being a function of the ranks of the observations rather than their actual values, not affected by the actual distribution of the data, and is less sensitive to outliers. The frequency of extreme rainfall events over India and significant inter-annual and inter-decadal variations in addition to a statistically significant long-term trend of 6% per decade is reported by Rajeevan *et al*. (2008). Raichur is one of the hot tropical districts in the North-Karnataka. It is extremely vulnerable to the impact of climatic events. Every year it faces extreme weather events either in the form of severe drought or floods along with extremely high temperatures in summer. It has a severe impact on crop production and the socio-economic status of farming families and results in huge revenue losses. Therefore, the needs for continuous rainfall studies are to be emphasized for long-term water resource planning and management. The main objective of these analyses is to examine the variability and trends in rainfall, rainy day, and minimum-maximum temperature for the period 1985-2019.

Rainfall, being considered as the prime input for agriculture has its own erratic behavior in terms of amount and distribution. For better crop planning, a detailed study on rainfall behavior is crucial. Rainfall variability, both in time and space influences the agricultural productivity and sustainability of a region, as opined by Virmani (1994). So, studying rainfall and its variability is becoming important for agricultural production and management. It was noticed that monsoon rainfall does not follow definite trend in India (Kripalani *et al.,* 2003) although some significant trends exist in some pockets of India when long term data are analyzed (Kolli *et al.,* 1992).

Rainfall amount, distribution, and intensity determine the choice of particular crop species and agronomic practices. Scientific study on the quantum and distribution of rainfall if made would enable the farming community to adjust or modify the cropping programmes as well as the cultural operations.

Matereial and methods

Monthly rainfall and temperature data for the past 35 years (1985-2019) were collected from the Meteorological Observatory, Main Agricultural Research Station (MARS), University of Agricultural Sciences, Raichur (16^0 12' N, 77^0 20' E and 389 m altitude. It is located in the North-Eastern Dry Zone of Karnataka. The annual, seasonal, and monthly rainfall and temperature data were critically examined for the entire study period. The seasons were decided as per IMD classification, *i.e*., monsoon from June to September (23rd to 39th meteorological week), post-monsoon from October to December (40th to 49th meteorological week), winter from December to February (49th to 9th meteorological week), and summer from March-May (10th to 22nd meteorological week).

Mann-Kendall test

For time-series data, the statistical significance of trends in rainfall data was carried out using standard Mann-Kendall trend test statistics using R studios (Jassby and Cloern, 2014). It is a non-parametric test used to find out fluctuations and presence of trend in time series data of rainfall, rainy day, and maximum and minimum temperature. The statistical significance was tested at a 95% level. The n time series values (X_1, X_2, X_3,....., X_n) are replaced by their relative ranks (R_1, R_2, R_3,....., R_n) (starting at 1 for the lowest up to n)

The Sen's slope is computed from M-K rank statistics (t)

t= 4"ni / n(n-1) -1

Where,

sgn (x) = 1 for x > 0

sgn (x) = 0 for x = 0

sgn (x) = -1 for x < 0

If the null hypothesis Ho is true, then S is approximately normally distributed

Results and discussion

Seasonal rainfall data from 1985 to 2019 have been analyzed and results reflected no significant trend at 95% level of significance using the time series data in all the cases except minimum temperature. Rainfall, the number of rainy days, and maximum temperatures have shown a non-significant decreasing trend across the seasons. Whereas, minimum temperature has shown a significantly increased trend during monsoon and summer seasons and a decreasing trend during post-monsoon season (Fig. 1 and Table 1). Seasonal rainfall (10%) was significantly increased over years during summer. This is indication of changes in the rainfall pattern of Raichur. Such changes in rainfall patterns may affect the timely agricultural practices around the Raichur. Similar observations on annual rainfall trends were also reported by Sastri *et al*. (1999). Whereas, Kolli *et al*. (1992) found that generally, monsoon rainfall does not follow any definite trend in India, although some significant trends exist in some pockets when long-term data were analysed. The frequency of occurrence of annual rainfall below normal

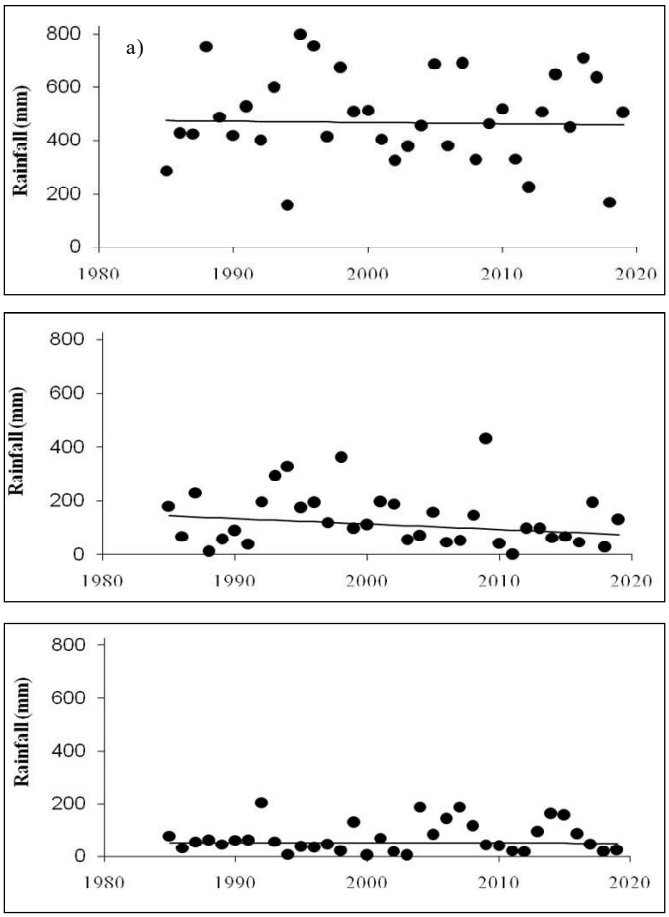

Fig. 1. Seasonal variation in rainfall received during southwest monsoon (a), post monsoon (b) and Summer (c) at Raichur, Karnataka, data points represents annual rainfall of each year from 1985 to 2019. Trend line represent Sen's estimator.

was increased after the 1990s (Fig. 3).

Meghdoot: Meghdoot app has been designed for general public and intends to enable easier access to real time weather based information**.** Meghdoot, a joint initiative of India Meteorological Department (IMD), Indian Institute of Tropical Meteorology (IITM) and Indian Council of Agricultural

Table 1. Monthly mean, highest and lowest rainfall (mm) along with SD and CV at Raichur, Karnataka (1985-2019)

Months	Lowest(mm)	Highest(mm)	Mean (mm)	% of Annual Rainfall	SD (mm)	CV (%)
January	0.0	36.6	3.1	0.4	7.5	240.4
February	0.0	32.0	3.0	0.4	8.0	265.8
March	0.0	102.0	10.8	1.5	24.2	224.6
April	0.0	114.2	17.4	2.5	24.4	139.9
May	0.0	205.6	42.5	6.1	48.6	114.4
June	8.8	313.4	99.3	14.2	77.8	78.3
July	9.0	306.8	105.0	15.0	67.8	64.6
August	11.3	372.9	126.9	18.2	83.9	66.2
September	0.8	316.6	153.3	21.9	89.8	58.6
October	0.0	362.6	111.1	15.9	97.8	88.0
November	0.0	155.0	17.6	2.5	29.7	169.1
December	0.0	69.8	5.0	0.7	15.3	306.5
Annual			695.0		201.3	29.0

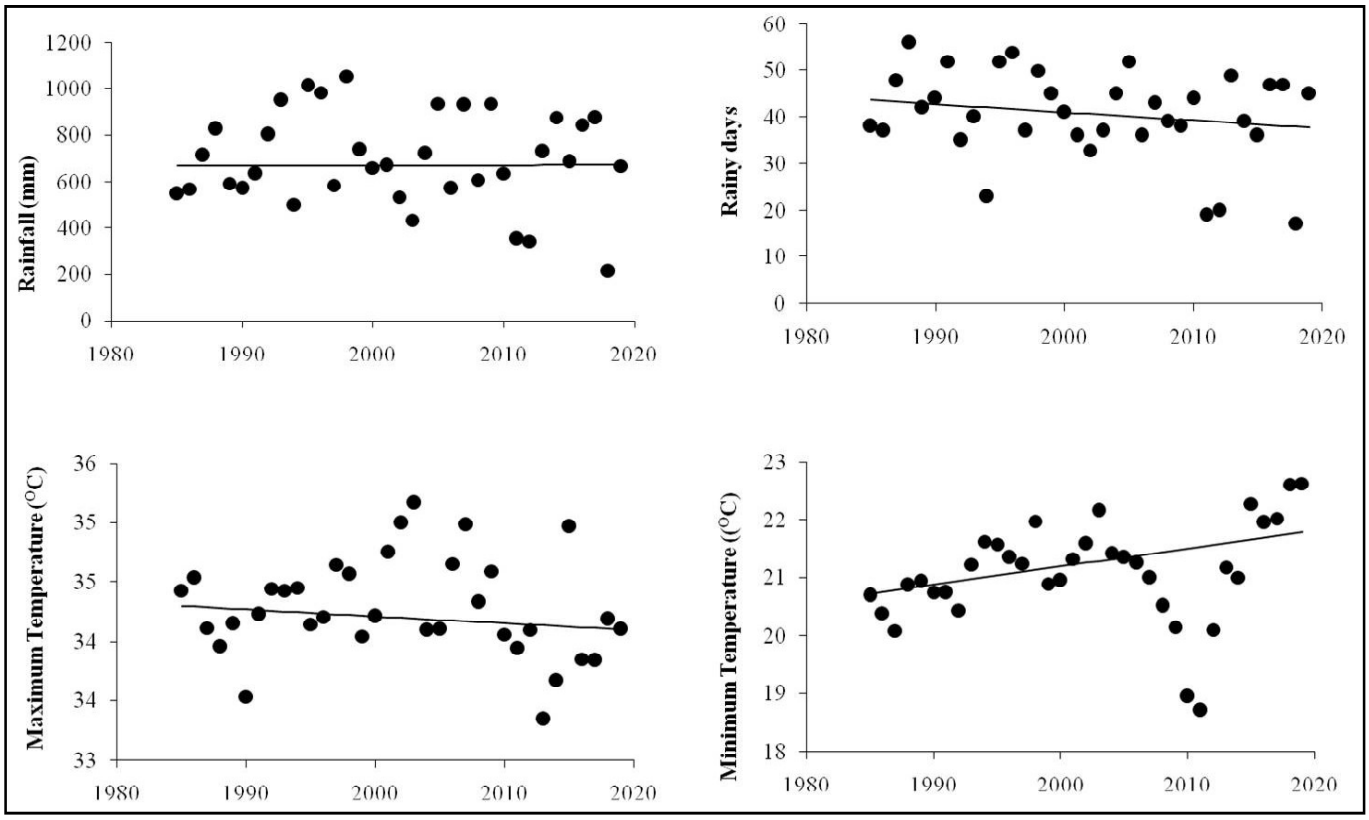

Fig. 2: Variability of annual rainfall, rainy day, maximum temperature and minimum temperature.

Table 2. Characteristics of seasonal rainfall (mm) at Raichur, Karnataka (1985-2019)

Seasons	Lowest (mm)	Highest (mm)	Mean (mm)	% of Annual Rainfall	SD (mm)	CV (%)
Monsoon	158	800	484.4	70	164.6	34.0
Post-Monsoon	0	430	133.7	19	102.4	76.6
Winter	0	40	6.1	0.9	11.1	182.4
Summer	4	206	70.7	10	57.2	80.9
Annual	216	1055	695.0		201.3	29.0

Monsoon: June-September, Post Monsoon: October-December, Winter: January-February Summer: March- May

Research (ICAR) aims to deliver critical information to farmers through a simple and easy to use mobile application. The mobile application was developed by the Digital Agriculture research theme at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad in collaboration with IITM, Pune and IMD, Delhi. The app seamlessly aggregates contextualised district and crop wise advisories issued by Agro Met Field Units (AMFU) every Tuesday and Friday with the forecast and historic weather information to the fingertips of the farmers. The advisories are also issued in vernacular wherever available

Damini: Damini Lightning apps is developed by IITM-Pune and ESSO. The apps is monitoring all lightning activity which are happening in specifically for all india. and alert you if lightning is happening near you by GPS notification. under 20 Km and 40 Km.

Rainfall Pattern

The overall mean annual rainfall for the past thirty-five years (1985-2019) of the Raichur region was 680 mm with a standard deviation (SD) of 201 mm and the coefficient of variation (CV) is 29 % (Table 1). The CV indicates the dependability or reliability of rainfall for any period. Lower CV values indicate better rainfall reliability having more or less stable rainfall over the years (Ramana Rao 1988).

As per the pattern of seasonal rainfall is concerned, it is quite evident from the data that the southwest monsoon contributes 70% (484.4 mm), post-monsoon 19% (133.7 mm), summer 10% (70.7 mm), and in winter <1% (6.1 mm) of annual rainfall. The coefficient of variation (CV) was more during winter (182.4%) indicated more variability of rainfall and a lower CV was found during monsoon (34%). Data indicated that over the years, September is the wettest month, which receives a maximum mean rainfall of 153.3 mm (21.9%) followed by August (126.9 mm and 18.2%). Monthly rainfall during December to March remained lowest in the range of 3 to 10.8 mm. It was also observed that the CV is less during June to September so there is higher dependability of rainfall and sure of occurrence during these months (Table 2).

***Temperature*:** The monthly highest temperature of 42.3^{0}C was observed in May 2003 and a minimum of 12.3^{0}C in January

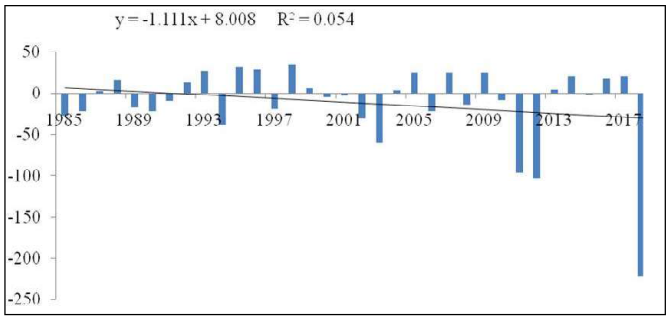

Fig. 3. Per cent departure from normal rainfall at Raichur, Karnataka (1985-2019)

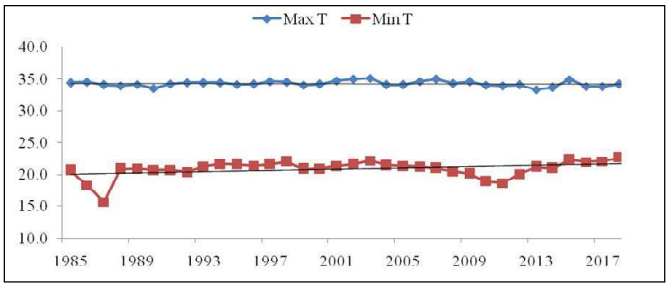

Fig. 4. Variation of the maximum and minimum temperature at Raichur, Karnataka

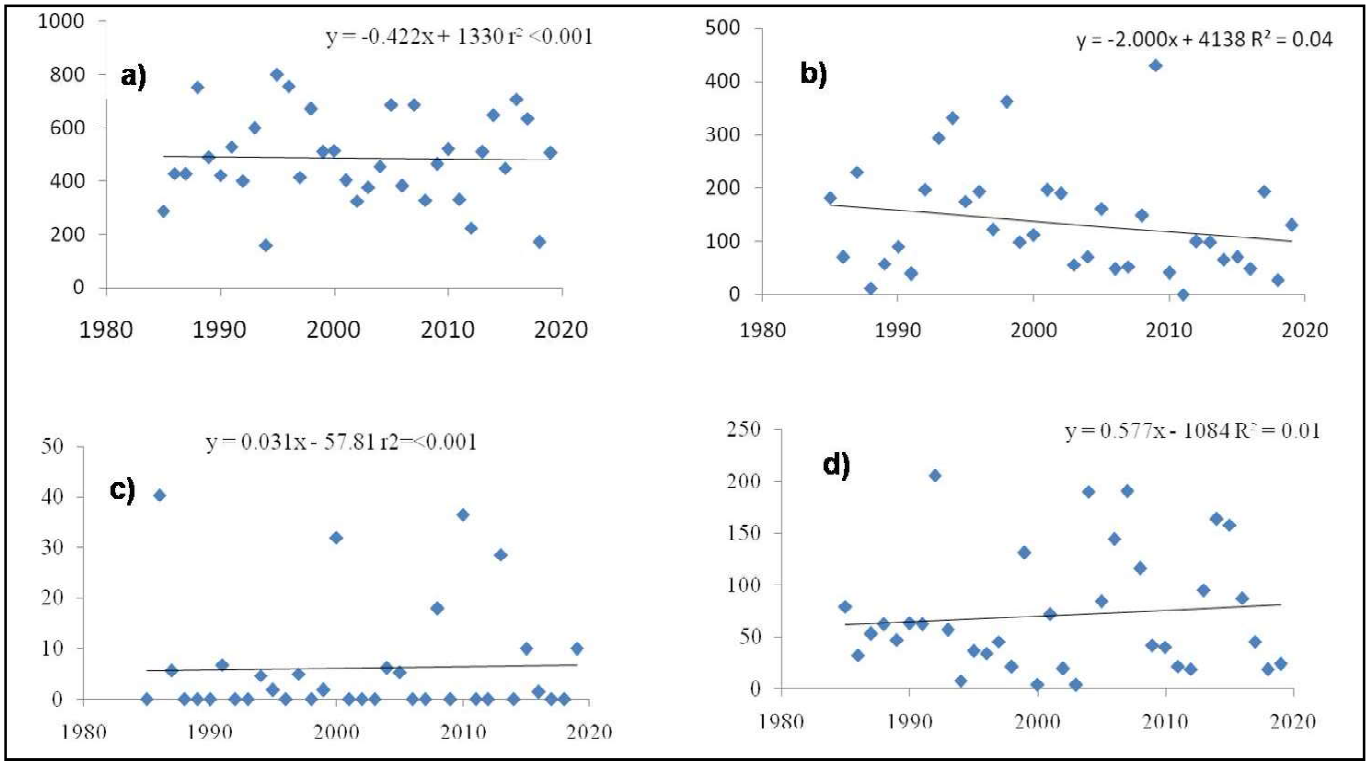

Fig. 5. Seasonal rainfall received during Monsoon (a), Post-monsoon (b), Winter (c) Summer (d) at Raichur, Karnataka. Each data points represents annual rainfall from 1986 to 2019

2011.

Crop planning

Since the delayed and weak onset of monsoon during June and July, 15 days interval staggered rice nursery should be grown in a small area at least two times. Intercropping of maize/ sorghum/ pearl millet with long-duration varieties of pigeon pea with raised bed may be used as agronomic measures. During deficit rainfall, foliar spray of 2% urea and potash would be beneficial to conserve moisture in the soil. Alternate furrow irrigation may be practiced to provide life-saving irrigation. For *Rabi* season crops like Bengal gram, long duration variety should be sown in 1st week of September while short-duration variety can be sown in 2nd week of September. This analysis might be helpful in the preparation of crop planning and management for the area in advance which would be greatly influenced the crop management and cropping pattern of the state positively.

After the 1990s the rate of decrease of the total quantum of annual rainfall was more in Raichur as compared to previous years (Fig. 3). The seasonal rainfall was also observed in decreasing trend in the order of post-monsoon > monsoon season > summer season rainfall. Decrease rainfall in January will affect the *Rabi* crops and pre-monsoon deficit while the delayed onset of monsoon will affect the *Kharif* crop production. Similarly, the decreased annual maximum temperature and an increased in minimum temperature will be helpful in high altitude regions for crop production.

Conclusion

Based on long-term data analysis (1985-2019) of Raichur, it was observed that all climatic variables changed over years. Based on the present study, the following recommendations

would be made to increase the land productivity in the region. During the pre-monsoon season based on information available normal rainfall receipt is too low for crop cultivation advice to take up land preparation, particularly summer ploughing. Alternatively, less water requiring short-duration crops such as millets, forage crops, and green manure crops, *etc*. can be grown with supplement irrigation practices. During *Kharif*, arable short duration crops like pulses, sunflower, millets, maize can be grown. In uplands and the embankments of water harvesting structures, the cultivation of cotton and vegetables can be grown after the cessation of northeast monsoon rains for effective utilization of land and other resources. Results also serve as a guiding tool for future yield predictions, crop simulation models, and climate change-related studies in the region.

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