Trend analysis of time series rainfall data using robust statistics

Arati Paul, Riddhidipa Bhowmik, V. M. Chowdary, Dibyendu Dutta, U. Sreedhar and H. Ravi Sankar

ABSTRACT

A temporal rainfall analysis was carried out for the study area, Rajahmundry city located in lower Godavari basin, India, during the period 1960–2013. Both the parametric and non-parametric approaches were envisaged for identifying the trends at different temporal scales. Linear and robust regression analysis revealed a negative trend at weekly scale during monsoon months, but failed to signify the slope at 95% confidence level. The magnitude of Sen's slope was observed to be negative during the months of April–September. Results of the Mann–Kendall test ascertained the negative rainfall trends during the monsoon months of June and July with a significant trend at 95% confidence interval. Application of robust statistics for long-term rainfall analysis helped to address the outlier's problem in the dataset. The Mann–Kendall test rejected the null hypothesis for all months except February–May and August after exclusion of outliers. Overall, a negative trend during monsoon season and a positive trend during post-monsoon season were observed using a robust non-parametric approach. Further, good correlation was found between the total rainfall and rainy days during the study period. On average, 21.25% days of a year is considered as rainy, while heavy and extreme rainfall in this region together occupies nearly 15% of the rainy days.

Key words | rainfall, rainy day, robust, significance, trend

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INTRODUCTION

A series of observations recorded in accordance with the time of occurrence is called 'time series'. Time series analysis measure the effect of variation components that helps in understanding the past behaviour and prediction of future tendencies in the dataset. Rainfall data are part of such meteorological time series data collected at specific time scales, i.e. daily, weekly, monthly, quarterly and yearly. Occurrence of daily rainfall is the most important environmental phenomenon and has a significant impact on climate, agriculture, economy and human activities. Understanding the variability of rainfall can lead us to address major environmental issues like droughts and floods. Further, an ever growing population and economic development is exerting enormous pressure on the water resources of the country. The Indian climate is dominated by the southwest monsoon and nearly 80% of the rainfall occurs during the four monsoon months (June–September) with large spatial and temporal variations over the country (Kumar *et al.* 2010). In India, the rainfall trend under changed climatic scenarios is very important as the economy and livelihood of the country are influenced by agriculture to a greater extent. The Intergovernmental Panel on Climate Change (IPCC 2007) reported that future climate change is likely to affect agriculture, increase the risk of hunger and water scarcity and lead to more rapid melting of glaciers (Kumar *et al.* 2010). Freshwater availability in many river basins in India is likely to decrease due to climate change (Gosain *et al.* 2006). Thus, an assessment of future water availability at different spatial and temporal scales is

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needed as changes in rainfall due to global warming is affecting the hydrological cycle rapidly. An analysis on hydrological response of a river basin under various climatic conditions can help to solve problems such as floods, droughts and water allocation. In India, studies have previously been carried out to determine rainfall trends at regional and national scales.

Studies in the past reported that the annual rainfall in India does not show any clear trend of increase or decrease (Thapliyal & Kulshreshtha 1991; Lal 2001). Although there is insufficient evidence to support the presence of a monotonic increasing/decreasing trend in the monsoon rainfall in India over a long period of time, particularly at an all India scale, significant long-term rainfall changes have been identified in few places (Dash *et al.* 2007; Kumar & Jain 2010a). Singh *et al.* (2008) studied the changes in rainfall in nine river basins of northwest and central India and found an increasing trend in annual rainfall. Studies carried out by several investigators have shown that the trend and magnitude of warming over India/the Indian sub-continent over the last century is broadly consistent with the global trend and magnitude (Arora *et al.* 2005; Dash *et al.* 2007). In general, a decrease in the number of rainy days and annual precipitation and an increase in the frequency of more intense rainfall events have been observed in many parts of Asia (Min *et al.* 2003; Dash *et al.* 2007). Significant rising trends in the frequency and magnitude of extreme rain events and a significant decreasing trend in the frequency of moderate events were observed over central India during the monsoon seasons from 1951 to 2000, which is computed based on a high resolution daily gridded rainfall dataset (Goswami *et al.* 2006). Mall *et al.* (2007) inferred a westward shift in rainfall activity over the Indo-Gangetic Plain region. Basistha *et al.* (2009) observed a decreasing trend in the Indian Himalayas during the last century as a sudden shift, rather than a gradual trend. A decrease of annual and monsoon rainfall at national scale was reported by Kumar *et al.* (2010). A decreasing trend was also found in the annual rainfall and rainy days in 15 out of 22 basins in India (Kumar & Jain 2010b). Spatio-temporal rainfall analysis in the Wainganga river basin located in Central India revealed a decreasing trend during the period 1949–2012 (Taxak *et al.* 2014). The dominant role of global warming on recent rainfall changes in India was observed over the last half century (Lacombe & McCartney 2014). The long-term monsoon patterns are believed to be influenced by anthropogenic climatic changes (Turner & Annamalai 2012). Patle & Libang (2014) reported a decrease in the rainfall pattern during the post monsoon season that may have an impact on vegetable and fruit production in the winter season in the north-eastern region of India.

Analysis of rainfall trend plays an important role in climate change studies for water resources planning and management (Haigh 2004). Though the monsoon rainfall in India exhibited no significant trend over a long period of time, few studies reported significant long-term rainfall changes at regional or local levels (Jain & Kumar 2012). Thus, analysis of rainfall variability at a specific location is a matter of great concern for assessing the amount of fresh water availability to meet the water demand for domestic and agricultural purpose. Hence, in this study, weekly, monthly, seasonal and annual rainfall trend analysis was carried out for the case study area using parametric (linear regression and robust linear regression) and non-parametric (Mann–Kendall and Sen's slope) approaches.

STUDY AREA AND DATA USED

Rajahmundry city, situated in the lower Godavari basin, East Godavari District, Andhra Pradesh, India, was selected as a case study area for rainfall trend analysis (Figure 1). Godavari is the third largest river in India with an annual runoff of 119 km^3, creating wide long valley on both sides. Godavari basin receives the major part of its rainfall during the southwest Monsoon period. The annual rainfall of Godavari varies from 600 to 3,000 mm. Daily rainfall data were collected from the meteorological observatory located at the Central Tobacco Research Institute (latitude 17°01′23″ N, longitude 81°47′45″E) farm for the period 1960–2013, i.e. nearly 54 years.

METHODOLOGY

A trend is a significant change over time exhibited by a random variable, detectable by statistical parametric and non-parametric procedures. Long-term rainfall trend analysis was carried out for the study area using parametric

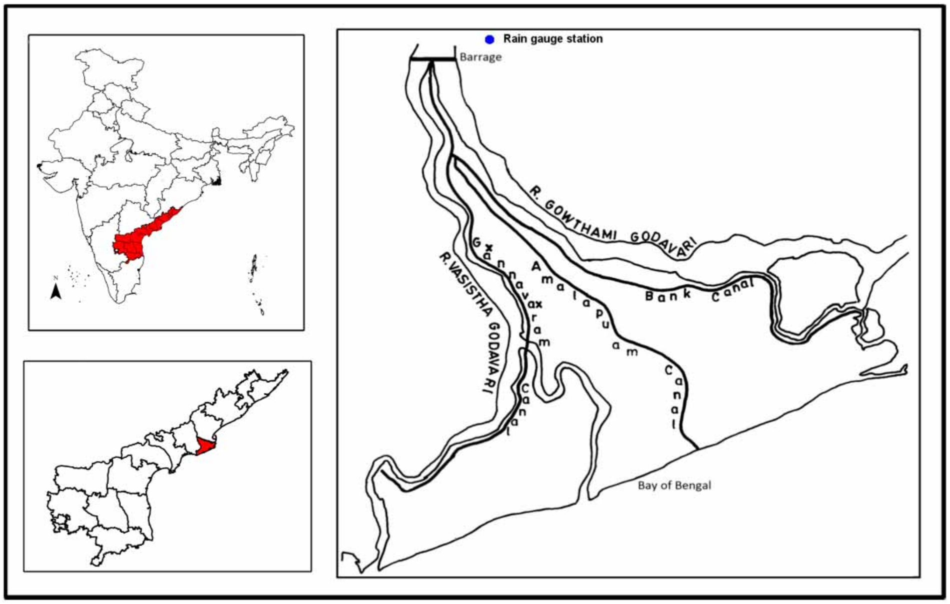

Figure 1 | Index map of the study area.

(linear regression and robust linear regression) and non-parametric (Man–Kendall and Sen's slope) approaches. Rainfall, being a natural phenomenon, sometimes produces extreme observations (extreme rainfall events) that occasionally significantly impact the general trend. Robust statistics are less sensitive to outliers and hence are used in this study. Parametric linear regression and non-parametric Mann–Kendall tests were performed to identify the trends in the rainfall pattern with/without outliers. The significance of trend was tested at 95% level of significance at different time scales.

Descriptive statistics

Descriptive statistics include mean, variance, standard deviation, skewness, kurtosis, total rainfall, minimum and maximum rainfall. Mean or average is the central tendency. Standard deviation is a measure of dispersion that indicates the variability and reliability of the rainfall in terms of its persistence. In other words, rainfall with a high standard deviation is considered more volatile than rainfall with a low deviation. Skewness is a measure of symmetry and Kurtosis is a measure of data peakness or flatness relative to a normal distribution, which indicate whether the data follow normal distribution or not.

Parametric linear regression methods

Simple linear regression

Trend analysis of monthly rainfall was carried out using an ordinary least square (OLS) based linear regression method (Das 2008) with time as the independent variable and rainfall as the dependent variable. The null hypothesis of linear regression is H_0: $\beta = 0$, i.e. slope is equal to zero. The significance of the slope is tested at 95% confidence interval.

Robust linear regression

Robust statistics (Huber 1981) were developed for good performance of data drawn from a wide range of probability distributions, especially from distributions that are not normal. The perception is to develop statistical methods that are not unduly affected by outliers. The sample mean y can be upset completely by a single outlier; if any data value $yi \to \pm\infty$, then $y \to \pm\infty$. This contrasts with the sample median, which is little affected by moving any single value to $\pm\infty$. In fact the median will tolerate up to 50% gross errors before it can be made arbitrarily large; we say its *breakdown point* is 50% whereas that for the mean is 0%. Robust methods aim to have high efficiency in a neighbourhood of the assumed statistical model (Street *et al.* 1988). Hence, in this study the robust linear regression model was used to analyse the rainfall variability on a weekly scale during monsoon season.

Non-parametric method

Onoz & Bayazit (2003) showed that the parametric *t*-test has less power than the non-parametric Mann–Kendall test when the probability distribution is skewed, but they can be used interchangeably with identical results in most cases. In this study, significance and magnitude of trend was estimated using the non-parametric Mann–Kendall test and Sen's method respectively.

Mann–Kendall test

Mann (1945) 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' (Kendall 1962). Mann proposed to test the null hypothesis (H_0) that data come from a population where the random variables are independent and identically distributed (IID). The alternative hypothesis (*H1*) is that data follow a monotonic increasing/decreasing trend over time (Kendall 1975; Gilbert 1987). In this study the Mann–Kendall test was used to identify the monotonic trend (increasing/decreasing) for time series data at different time scales based on the normalized Z statistics value. Negative and positive values of the Z statistics represent the decreasing and increasing trends of rainfall, respectively.

Sen's estimation of slopes

The magnitude of trend in a time series is determined either by using regression analysis (parametric) or by using Sen's estimator method (non-parametric) (Sen 1968; Jain & Kumar 2012). Both these methods assume a linear trend in the time series. Sen's estimator was used to determine the magnitude of trend, i.e. change per unit time in hydrometeorological time series. The slope of the trend gave the rate of increase or decrease in the trend and direction of change (Choudhury *et al.* 2012).

Mann–Kendall test by excluding outlier from the population

The idea of robust regression (Huber 1981) is to weigh the observations differently based on how well they influence the estimator. An observation is said to be influential if removal of the observation significantly changes the estimate of the regression coefficients. Leverage is a measure of how far an independent variable deviates from its mean. An observation with an extreme value is a point with high leverage, so the data with high leverage value are given less weight. Less weight indicates less influence to the regression line (Holland & Welsch 1977). As rainfall is a natural phenomenon, sudden heavy rainfall can affect the quantity of total rainfall or the average rainfall. Hence, to find most common behaviour of each month a robust regression analysis technique was used to detect the outliers in data and the previous test is again performed by excluding the outliers.

Rainfall intensity analysis

A day is considered to be a rainy day if the rainfall is greater than or equal to 1 mm. Rainfall intensity can be obtained in two ways, either dividing the total annual rainfall by total rainy days or dividing the rainfall into four groups consisting of light rainfall ($<$10 mm); moderate rainfall ($\geq$10 to $\leq$25 mm); heavy rainfall ($>$25 to $\leq$50 mm) and extreme rainfall ($>$50 mm) (Kwarteng *et al.* 2009). In this study, both these approaches were followed.

RESULTS AND DISCUSSION

Descriptive statistics of the data

Descriptive statistics, viz. mean, variance, standard deviation, skewness, kurtosis, total rainfall, minimum and maximum rainfall, were computed on a monthly scale for the study period (Table 1). A high standard deviation of the data under consideration suggests that year-to-year fluctuations are high while a low standard deviation indicates

Table 1 | Descriptive statistics of monthly rainfall

Month	Mean	Max	Min	SD	Var	Skewness	Kurtosis	Sum	Range
Jan	0.70	83.60	0	4.90	24.30	9.70	115	21.16	83.60
Feb	0.61	107.30	0	5.45	33.12	10.66	137.43	18.06	107.30
Mar	0.70	205.60	0	6.70	45.10	20.40	551.60	20.32	205.60
Apr	0.65	68.80	0	4	16.30	9.30	109.10	19.05	68.80
May	1.90	218.60	0	10	99.10	12.60	227.30	59.34	218.60
June	4.20	216.20	0	11.90	141.30	6.40	77.90	126.64	216.20
July	6.93	200	0	13	178	5	44	202.41	200
Aug	6.99	150	0	15	222	4	26	204.70	150
Sep	5.60	196.40	0	13.80	190.60	5.60	53.60	167.98	196.40
Oct	4.60	166.20	0	13.10	171	5.40	45.10	141.26	166.20
Nov	1.70	156.10	0	8.50	71.80	10.40	147.30	51.01	156.10
Dec	0.70	79.10	0	7	136	10.05	123.52	50.00	79.10

that fluctuations are lower. Skewness was calculated every month and then the average skewness value was computed for 54 years, which indicated that skewness was positive for all the months. The positive value of skewness for all months implies that rainfall occurring at the end of a month is greater than rainfall occurring in the beginning. From the results it is observed that the annual rainfall distribution under the study period does not follow normal distribution. It can be inferred from Table 1 that the maximum total annual rainfall of 204.70 mm in 54 years with the corresponding mean of 6.99 mm per month per year occurred in the month of August, next the maximum mean of 6.93 mm/month per year corresponding to the sum of 202.41 occurred in the month of July. The monsoon season in east Godavari district is spread among June, July, August and September months (Table 1). Pre-monsoon season (March–May) and post-monsoon season (November–February) reported very low rainfall. The maximum rainfall event of 218.6 mm occurred on 9th May, 1989 during the entire study period, which was a non-monsoon month.

Parametric linear regression methods

Simple linear regression

Coefficients of the linear regression equation computed for all the monsoon months indicated negative slopes (Table 2). The null hypothesis was rejected for the months of January, June, July, September and December as the *p*-value was less than the significance level, i.e. 0.05, while in the case of other months null hypothesis failed to reject as the *p*-value was greater than 0.05. Based on the *p*-value, there is insufficient evidence to support the presence of a monotonic increasing/decreasing trend in the series for these months. OLS methods for regression analysis are highly sensitive to outliers, as it compromises the validity of the regression results.

Table 2 | Results of linear regression analysis by least square method

Months	Intercept	Slope	*P*-value	Null hypothesis rejected?
January	−0.54	0.04	0.04	Yes
February	0.03	−0.20	−0.20	No
March	0.03	0.02	0.02	No
April	0.66	0.00	0.00	No
May	2.25	−0.01	−0.01	No
June	5.89	−0.06	−0.06	Yes
July	8.98	−0.09	−0.09	Yes
August	7.41	−0.03	−0.03	No
September	6.57	−0.04	−0.04	No
October	4.59	0.00	0.00	No
November	0.90	0.03	0.03	No
December	−0.65	0.05	0.05	Yes

Robust linear regression

Weekly rainfall analysis was carried out to analyse the rainfall variability during the monsoon season using a robust linear regression model.

Coefficients of regression analysis carried out using OLS and robust regression approaches are presented in Table 3. It can be observed from Table 3 that negative slopes were obtained for all the weeks in the case of both approaches except for a few weeks (2nd week of June, in both the methods; 1st week of August and 2nd week of September in robust regression). Therefore, the rainfall pattern indicated a decreasing trend with time. The significance of the slope is shown by the *P*-value and tested for its significance at 0.05 level. The null hypothesis failed to reject for all the weeks except the 1st and 4th weeks of June 1st and the 1st week of July as *P*-values of slopes in the case of OLS method are greater than the significance level 0.05, which indicated a lack of evidence to support the presence of monotonic increasing/decreasing trends on a weekly scale during the monsoon season. The robust method for linear regression also supports the result of hypothesis testing using the OLS method. However, it is clear from Table 3 that estimation of slopes using robust regression analysis is more effective (Figure 2).

Table 3 | Comparison of least square regression and robust regression

Week no.	Slope (OLS)	Intercept (OLS)	*P*-value (OLS)	Slope (robust)	Intercept (robust)	*P*-value (robust)
June 1st	−0.45	6.03	**0.01**	−0.46	6.15	**0.01**
June 2nd	**0.11**	2.91	0.69	**0.03**	3.09	0.90
June 3rd	−0.30	6.61	0.41	−0.50	6.91	0.93
June 4th	−0.58	8.15	**0.00**	−0.57	8.14	**0.01**
July 1st	−0.89	11.95	**0.02**	−0.66	9.83	**0.02**
July 2nd	−0.13	6.24	0.69	−0.01	5.41	0.97
July 3rd	−0.19	7.67	0.54	−0.15	7.55	0.66
July 4th	−0.67	10.86	0.07	−0.67	10.82	0.81
Aug 1st	−0.03	8.23	0.95	**0.51**	6.12	0.09
Aug 2nd	−0.17	8.67	0.74	−0.13	8.23	0.81
Aug 3rd	−0.37	7.00	0.15	−0.37	6.96	0.19
Aug 4th	−0.20	7.10	0.47	−0.21	7.05	0.50
Sep 1st	−0.08	5.54	0.75	−0.08	5.41	0.74
Sep 2nd	−0.24	6.51	0.44	**0.25**	2.16	0.17
Sep 3rd	−0.19	7.15	0.61	−0.20	7.19	0.61
Sep 4th	−0.26	7.45	0.39	−0.28	7.47	0.40

The effect of outlier on least square regression is evident from Figure 2(a)–2(d). It can be observed from the figures that the effect of outliers on the regression line is more compared to the robust regression line. Particularly, the trend line shifts towards outliers in the case of the OLR approach. Overall, the linear regression line indicated negative slope.

Non-parametric approach

The significance and magnitude of trend in the rainfall data were estimated using the non-parametric Mann–Kendall test and Sen's method respectively in this study. The results of the Mann–Kendall test and Sen's slope estimation are given in Table 4. It is observed in Table 4 that Z values are negative during the monsoon season (June–September) while positive during both pre- and post-monsoon season months (except April and May).

Significance of trend

The significance of trend was tested to reject or accept the null hypothesis (H_0). The Mann–Kendall hypothesis test results show that H_0 is rejected for the months of June and July at the 95% confidence interval, which indicated a downward or decreasing trend in total rainfall for these two months. H_0 failed to reject for other months that indicated no significant trend in total rainfall for these months and data belong to a population which is IID.

Magnitude of trend

Results of the Mann–Kendall test ascertained that the rainfall trend during the non-monsoon months is not significant. A generalized positive trend was observed for January, February, March, October, November, and December during the study period, while a negative trend was observed for June and July with a significant trend at 95% confidence level ($\alpha = 0.05$). Decadal trend analysis of rainfall indicated positive Sen's slope for January (Table 4) but the rainfall trend between two periods (1960–1969) and (1970–1979) is negative. The mean change in the total rainfall for these two periods is −81.40 mm. Therefore, it can be

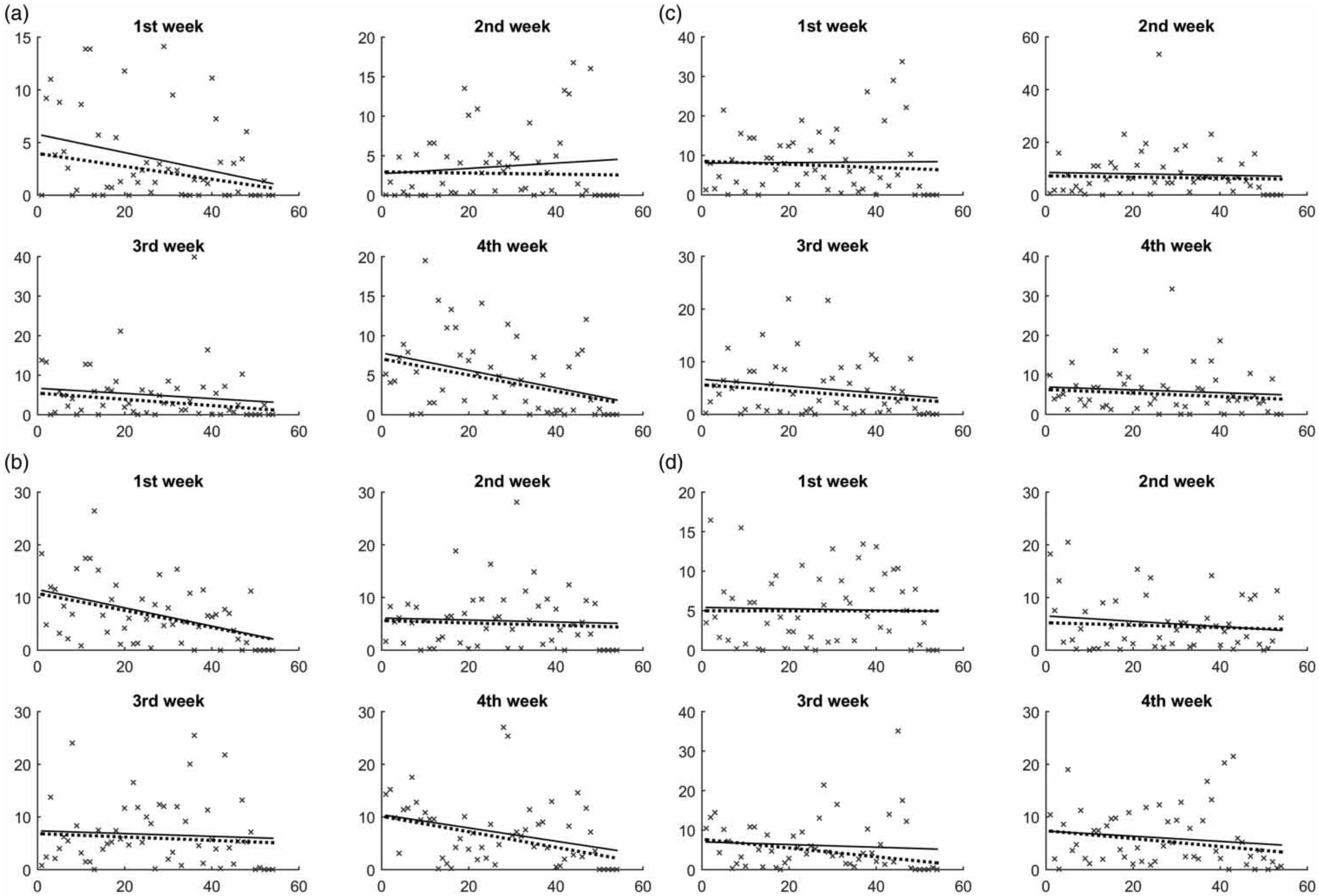

Figure 2 | Weekly rainfall analysis: least square regression vs robust regression: (a) June, (b) July, (c) August, (d) September. Y-axis represents average rainfall in mm, X-axis represents years.

Table 4 | Results of Sen's slope estimation and Mann–Kendall test

Month	Sen's slope	Z value	H_0 rejected?
January	0.32	1.13	No
February	0	0.98	No
March	0	0.26	No
April	−0.52	−0.51	No
May	−0.34	−1.02	No
June	−3.97	−2.84	Yes
July	−3.02	−3.25	Yes
August	−4.05	−0.91	No
September	−5.12	−1.38	No
October	7.35	0.12	No
November	1.32	0.23	No
December	0	1.14	No

easily seen that between these years the trend value of rainfall decreased by −26.05 (−81.40*0.32) units, while the other successive differences are positive.

Sen's slope was observed to be negative during April–September (Table 4). Although slope was negative for the month of April, positive changes were observed between the periods (1970–1979) and (1980–1989) and also between 1990–1999 and 2000–2009. The difference of total rainfall between these time periods was 252.4 and 60.6 mm respectively. Hence the magnitude of rainfall was increased by 131.25 and 31.51 units respectively between these periods. An increasing trend was observed for the month of May between two periods (1970–1979 and 1980–1989), where the total rainfall was increased by 881 mm indicating an increase in the change by 299.54 units (obtained by multiplying total rainfall with the value of Sen's slope from Table 4).

An increasing trend was also observed for the month of June between the periods 1970–1979 and 1960–1969 in 2,331.82 units, while the overall trend is negative. July also shows positive changes in total rainfall between the time periods 1970–1979 and 1980–1989 and 1980–1989 and 1990–1999, where rainfall was increased by 1,282.2 and 216.22 units, respectively. A similar pattern was also observed in the case of August, where total rainfall increased between time periods 1960–1969 and 1970–1979 and 1970–1979 and 1980–1989 with 3,484.4 and 1,620 units, respectively. Total rainfall in the month of November decreased by −629.88 units, between the periods 1970–1979 and 1980–1989.

Mann–Kendall test by excluding outlier

The Mann–Kendall test statistics failed to reject the null hypothesis for most of the months, when the whole dataset of each month was included for the test. Hence, rainfall analysis was carried out using the Mann–Kendall test by excluding outliers (Table 5). Null hypothesis failed to reject in the case of February to May and August as a significant monotonic increasing/decreasing trend was not found for these months. Most of the days in February, March and May were non-rainy days and rainy days present in these months were considered as outliers and omitted by the statistics. Null hypothesis is rejected for other months, which indicates the presence of a monotonic increasing or decreasing trend for these months. Overall a decreasing trend for June, July and September and increasing trend for January, October, November and December was observed (Table 5). As very low tendency of rainfall is observed in these months, more common behaviour was found for each of these months when outliers were removed.

Table 5 | Results of Mann–Kendall test by excluding outlier

Month	Z value	Null hypothesis rejected?
January	2.81	Yes
February	0	No
March	0	No
April	−0.51	No
May	0	No
June	−4.04	Yes
July	−5.34	Yes
August	−0.58	No
September	−2.55	Yes
October	3.28	Yes
November	4.37	Yes
December	3.28	Yes

Rainfall intensity analysis

The mean and standard deviation of rainfall distribution under different quantities are estimated (Table 6). Distribution of rainy days during the period 1960–2013 is shown in Figure 3. The highest and lowest average number of rainy days was observed in the case of rainfall less than 10 mm per year and more than 50 mm per year, respectively (Table 6). The ratio of average number of rainy days to average number of non-rainy days is nearly four times, which is very high. On average it rains 21.25% days in a year. Out of this, nearly 60.36% days of rainy days experienced rainfall less than 10 mm, while 24.47% days of rainy days experienced rainfall with 10–25 mm per day

Table 6 | Results of rainfall intensity

Type of days	Mean (days/year)	SD
Non rainy	287.69	15.25
Rainy	77.56	15.17
With rain <10 mm	46.82	11.73
With rain 10–25 mm	18.98	4.79
With rain 25–50 mm	9.04	3.39
With rain >50 mm	3.37	1.84

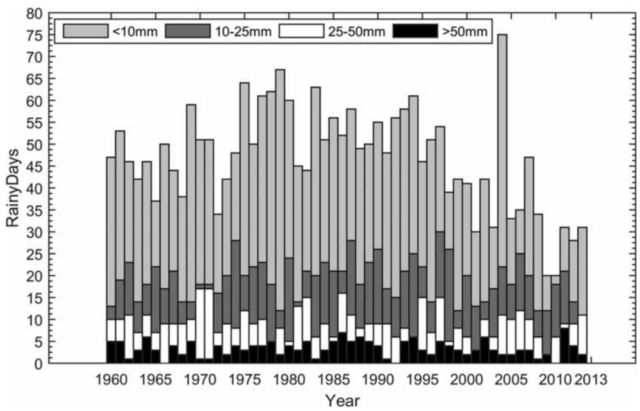

Figure 3 | Distribution of rainy days from 1960 to 2013.

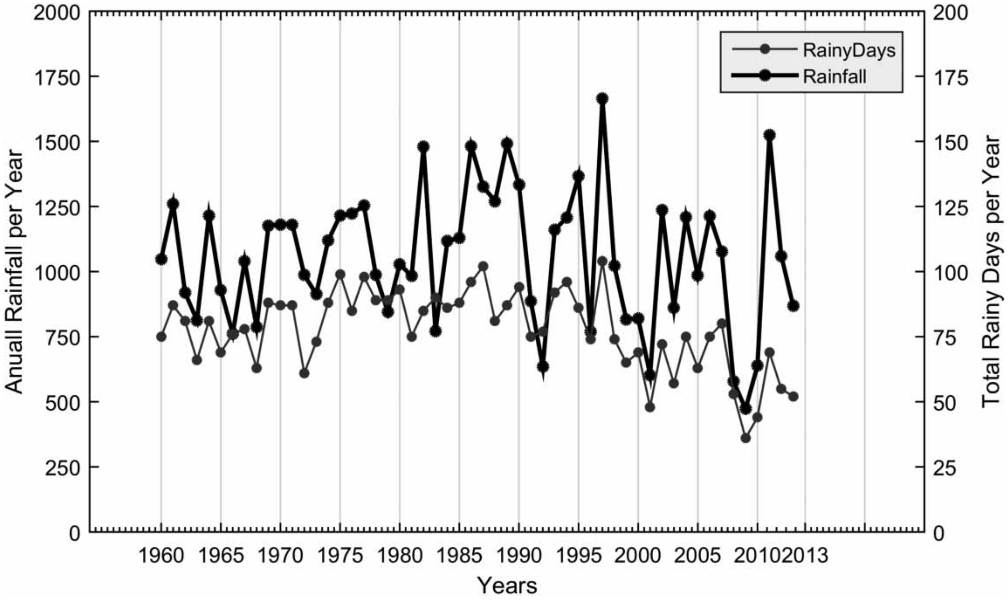

Figure 4 | Relation between total annual rainfall and total rainy days per year in East Godavari.

category. Heavy rainfall (25–50 mm) and extreme rainfall (rainfall >50 mm) in this region occupies 11.65 and 4.35% of the rainy days respectively.

The correlation between the annual rainfall and annual rainy days is shown in Figure 4. Similar patterns can be observed for the entire study period between annual rainfall and annual rainy days (Figure 4). The maximum number of rainy days (104) occurred in the year 1996, which also corresponds to the maximum annual rainfall of 1,664 mm.

The rainfall intensity (total rainfall divided by total rainy days) was also computed for the entire period (Figure 5). The positive slope of robust regression line, i.e. 0.05 units, indicated an increasing trend with time. Further, the null hypothesis of linear regression was also tested at 95% confidence interval and was rejected as the P value of the estimated parameter is 0.03 (<0.05).

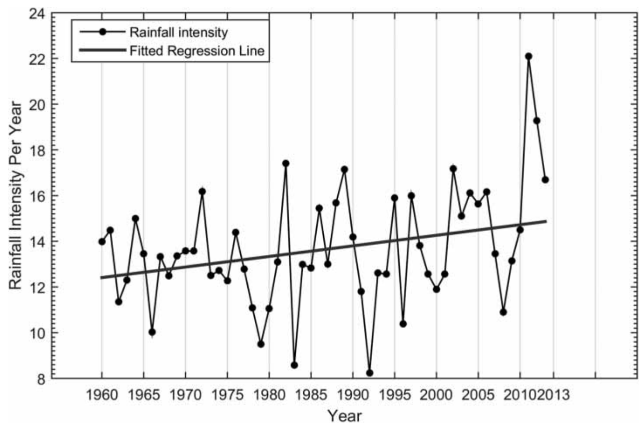

Figure 5 | Robust regression line fitted to rainfall intensity in each year.

CONCLUSIONS

Long-term rainfall data for the period (1960–2013) were analysed for identifying trends at different temporal scales, i.e. weekly, monthly and yearly scales for the case study area located in the lower Godavari basin. Descriptive statistics indicated that the time series data are positively skewed and are not normally distributed. Linear regression analysis inferred that a non-significant negative trend exists for monsoon months, while downward trends were observed at a weekly scale for all the monsoon season months using robust regression. The non-parametric Mann–Kendall test also reported the decreasing trend during the monsoon season over the study period. The analysis did not indicate a significant monotonic increasing/decreasing trend in all the months except June and July. Further analysis with the exclusion of outliers indicated rejection of null hypothesis for all the monsoon months except August with a falling trend. Mann–Kendall and regression analysis indicated that there are falling and increasing trends during monsoon and post-monsoon seasons, respectively, at 95% level of significance. Studies on annual rainfall distribution reported that the study area experiences rainfall for nearly 21.25% days per annum. Out of this nearly 60% of the days had rainfall less than 10 mm. Rainy days and rainfall had a good correlation during the study period at this station and rainfall intensity is increases as the year increases. Thus, temporal analysis of rainfall helps to understand the changing pattern of rainfall occurrence at multiple temporal scales. Identifying the rainfall trends is one of the most important prerequisites for planning water resources for irrigation purposes.

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