International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133; Print ISSN: 2664-7125; Impact Factor: RJIF 5.28
Received: 28-01-2021; Accepted: 28-02-2021; Published: 17-03-2021
Volume 3; Issue 1; 2021; Page No. 433-439

Statistical study on trend analysis of rainfall distribution in southern Odisha

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Abstract
The impact of world global climate change on agriculture has been increasingly realized during previous few decades. The importance of rainfall has been found to be significantly changed over the last three decades particularly in Southern Odisha, India. The present study aims to identify the trends in annual and seasonal rainfall and its magnitude in Southern Odisha. During this study, the mean monthly and seasonal rainfall this districts are analysed to determine the trend and its magnitude for the quantity of 1982-2014. The logical thinking is completed using Mann-Kendall and Sen's slope estimator. The study showed a giant declining rainfall trend particularly within the month of February and November with p value of 0.45 and 0.48 respectively. An increasing trend of Rainfall with p value 0.34 within the month of September. The analysis results showed wide variations during all the seasons. The increasing trend of rainfall is found to be dominant during south-west monsoon season compared to other seasons. The study attempts for to anticipate the supply of irrigation for agriculture especially within the summer and winter seasons.

Keywords: rainfall, mann-kendall test, sen's slope estimator, agriculture, trend analysis

Introduction

Rainfall, the potential sources of moisture and basic climatic factor, is that the dominant single weather element influencing things and nature of the farming system. It determines the potential of any region in terms of crops to be produced, the farming system to be adopted, the character and sequence of farming of operations to be followed, and to achieve higher agricultural productivity moreover. Detailed knowledge of the rainfall regime at a district may be a crucial prerequisite for agricultural planning and management. Around 60% of Indian agriculture is rain-dependent, distress prone, and liable to climate. Climatic variability, particularly rainfall is that the most important factor influencing the agricultural productivity and sustainability within the tropics. Recent studies indicate the increase in temperature with rainfall uncertainties may lead to a loss of 10 to 14% crop production in India because of its large population and limited resources (Parry *et al.*, 2004) [1]. Rainwater management and its optimum utilization might be a chief issue of present-day research for sustainability of rainfed agriculture. So on accommodate the matter, detailed knowledge of rainfall distribution can help decide the time of varied agricultural operations and crop planning. Crop planning of an area depends upon the number of things, namely the kind of crops, climate, soil characteristics, topography, and socio-economic condition. The knowledge on annual and seasonal rainfall of a part is useful to style a water harvesting structure for agricultural operations, field preparation, seeding, irrigation, fertilizer application, and overall within the sector of crop planning. Therefore, the seasonal trend of rainfall is helpful for crop planning in an exceedingly vicinity. The long-term rainfall of the state varies between 961 and 1872 mm. However, the standard annual rainfall of the state is about 1438 mm. the weather of the Odisha State is extremely humid with medium-to-high rainfall, tropical and short winter with mild temperature. The southern Odisha consist of 10 districts, these are Ganjam, Gajapati, Kandhamal, Boudh, Kalahandi, Nuapada, Koraput, Nabarangapur, Rayagada, and Malkangiri. As per Koppen's climatic classifications Southern part of Odisha comes under the AW having a tropical Savannah type of climate. The south-west monsoon normally sets in between 5th June and 10th June in the coastal plain, and by 1st July the whole of the state is under the full sway of the south-west monsoons as per ENVIS Centre of Odisha's State of Environment. As Ganjam district is the biggest district in Southern Odisha so present study is carried out by taking rainfall data of Ganjam Distict. The varying intensities of cyclones, drought, and flood occur almost each year in most of the districts, mostly within the Ganjam District. Changes within the pattern, frequency, and variability of SW monsoon would have an enormous impact on agricultural production, water resources management, and overall economy of the country [2, 3]. Seeable of the above, sort of studies have attempted to research the trend of climatic variables for the country. These studies have confirmed the trends on the country scale [4, 5, 6], regional scales [7, 8, 9, 10, 11], and at the individual stations [12, 13]. The logical thinking of rainfall [14, 15] temperature [16, 17, 18] and other climatic variables on different spatial scales will help within the development of future climate scenarios. Hence, this study attempts of trends analysis of rainfall in Southern Odisha in line with the foremost appropriate tests both monthly and annual data. Mann-Kendall trend test is one in every of the techniques widely used for environmental and climate studies, the first advantage is that the weakness of sensitivity to abrupt breaks that may be caused inhomogeneous statistic. The second advantage is data file of this test doesn't require any special distribution. Moreover, the Sen' slope estimator formula has also been employed during this research which uses a linear model to estimate the trend for all the natural action parameters [19].

Material and Methods

Study area

Ganjam district is on 19.4 to 20.17 degree North latitude and 84.7 to 85.12 degree East longitude. It covers a section of 8070.60 sq. km. The district is broadly divided into two divisions, the coastal area within the east and hill and table land within the west. The Eastern Ghats line the western side of the District. The climate of Ganjam is characterized by an equable temperature around the year, particularly within the coastal regions. The district's cold seasons from December to February is followed by hot season from March to May. The normal rainfall of Ganjam is 1331.8mm received in 64.2 rainy days out of which 847.2mm rainfall is received within 43.7 rainy days June to September. Pre monsoon rainfall is received during April and can is helpful for land preparation and post monsoon rainfall of 155.9 mm is received in 9.5 rainy days.

Data and its sources

Monthly rainfall data for 30 years was collected from the Director of Agriculture and Food Production, Special Relief Commissioner (SRC) and India Meteorological Department (IMD). The rainfall data was measured in mm and used for this study for the quantity 1990-2019. Data analysis was done using XLSTAT, and EXCEL.

Trend Analysis

Various statistical tests are used for thought (Spearman Neumann, Cramer, Pearson, Buishand, rank statistic, Pettit, Standard normal homogeneity test [SNHT]); but it's considered that Mann Kendall Statistical test is best for the analysis of climatic changes and predict of the abrupt changes in climatically statistic and it's the foremost non-parametric test used frequently. To work out the magnitude of the trend, Sen's Slope estimation is employed which complements Mann Kendall's test. The knowledge were analysed to spot significant trends for climatic indicators using the Mann- Kendall statistics test which has the following: Mann-Kendall test has been employed in hydrological trend detection studies. The analysis by Mann-Kendall will set data time sequential order, and for beginning must compute significance (Sgn) of the difference between consecutive sample outputs.

The results of Sgn will be in the values 1, 0, or –1 according to the significance of $X_j - X_i$

Where j >i, the formula was computed as:

- $if\ X_j - X_i > 0 \ldots\ldots\ldots\ sgn(X_j - X_i) = 1$
- $if\ X_j - X_i > 0 \ldots\ldots\ldots\ sgn(X_j - X_i) = 0$
- $if\ X_j - X_i > 0 \ldots\ldots\ldots\ sgn(X_j - X_i) = -1$

Where, X_j and X_i are the sequential rainfall or temperature or humidity values in months J and i (J>i) respectively and a positive value is an indicator of increasing (upward) trend, and when an indicator is of decreasing (downward) trend, it is a negative value. It can be considered that X_1, X_2, X_3.....X_n present monthly data points, where X_j represents the data point at time J. Then the Mann-Kendall statistics (S) is defined as the total number of positive contrasts minus the number of negative contrasts as expressed in the following formula

$$:s = \sum_{n-1}^{k=1} \sum_{j=k+n}^{n} sgn(X_j - X_i)$$

The value of 'S' determines whether the trend is positive or negative; when it is high or low and the probability associated is needful to calculate with 'S' and the sample size 'n'. Normal approximations to the Mann-Kendall test may be used with significance of the trend for a. For this, the variance of S (Var S) when sample size > 10 is calculated as:

$$Var\ S = \frac{\left[n(n-1)(2n+5) - \sum_{g=1}^{m} tg(tg-1)(2tg+5)\right]}{18}$$

g = 1, 2,…, q

where $Var(S)$ is the variance of statistics Mann-Kendall; 'M' can be interpreted as the number of data that has the same value (tied group) and 'n' as the sum of available data, also 'tg' is the sum of the data points in the g[th] group. 'Z' (standardized test statistic) is calculated as:

- $When S > 0 \ldots\ldots Z = \frac{n-1}{\sqrt{var(S)}}$
- $When S = 0 \ldots\ldots Z = 0$
- $When S < 0 \ldots\ldots Z = \frac{n+1}{\sqrt{var(S)}}$

There are many values of 'Z' (1.645, 1.960, 2.576) used to determine the significance level of 10, 5 and 1 per cent respectively. Z-score follows a standard normal distribution and when the statistical significance is increasing or decreasing trend of temperature, humidity and average rainfall values, it is better to use. Generally, if the result is founded to be more than Za/2; it will be significant trend, where 'a' is significance level of testing if the trend is an upward or a downward monotone (a two-tailed test).

Sen's Slope Test

This test provides the trend magnitude of trend data sit of the time series. Then, for all data pairs, the slope (Q_i) can be calculated as follows:

$$Q_i = \frac{X_j - X_k}{j-k} \text{For i = 1,2,…..N}$$

Here at time (months J and i), it can be X_j and $X_i$as data values where j>i correspondingly. Q_i (Sen's estimator of slope) is represented by the average of these N values and it is: given, as

$$:Q_i = \begin{Bmatrix} Q_{\left[\frac{N+1}{2}\right]}\ if\ N\ is\ odd \\ \frac{Q_{\left(\frac{N}{2}\right)} + Q_{\left(\frac{N+2}{2}\right)}}{2}\ if\ N\ is\ even \end{Bmatrix}$$

The positive value of Q_i indicates an upward and increasing while a negative value of Q_i gives the opposite result of trend. Q_i is calculated at 100 (1-α) per cent confidence interval and by a two-sided test.

Coefficient of Variation

Coefficient of Variation (CV) is a measure of relative variability. It is the ratio of the standard deviation to the mean (average).

$$\text{coefficient of variation} = \frac{\text{Standard deviation}}{\text{mean}} \times 100$$

According to literature, CV is used to classify the degree of variability as less (CV < 20%), moderate (20 < CV < 30%), high (CV > 30%), very high (CV > 40%) and CV > 70% indicate extremely high inter-annual variability of rainfall. Based on this, from the observed data considered that all the months had above 30% of CV highlighting the high variability of precipitation over the area.

Results and Discussion

In this study (1990-2019), rainfall data has been analyzed with Kendall [20] and Sen's Slope estimator for determination of the trend.

Statistics of climate indicators

Statistical analysis of all data sets was carried out over the period of study. The skewness has been used to determine asymmetry in a frequency distribution around the mean while kurtosis has been used for describing the higher point of a symmetrical frequency distribution as a statistic parameter.

Table 1: Statistical properties of Seasonal and annual rainfall of Ganjam district (1890-2019)

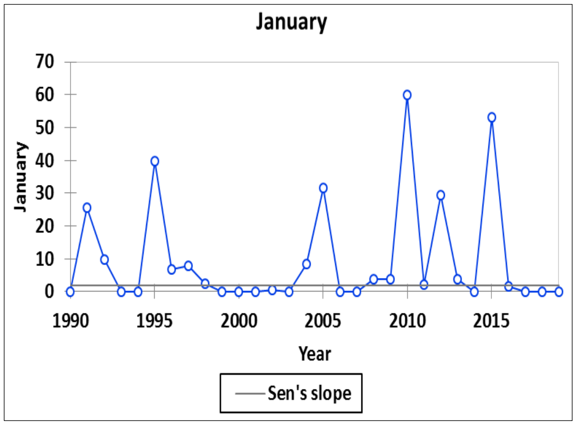
	mean	SD	CV	Skewness	Kurtosis
January	9.7	16.64208	172.0973	1.957697	2.947912
February	14.5	23.68802	163.6489	2.578592	6.083711
March	21.7	27.36391	126.2728	1.830558	3.654088
April	33.5	21.58408	64.42775	0.594528	-0.14469
May	87.7	108.485	123.737	3.758949	6.36382
June	162.6	75.72057	46.56011	0.39403	-0.07464
July	233.8	83.33555	35.64279	0.649092	-0.34266
Auguest	272.7	83.47189	30.61233	0.991159	2.231018
September	229.6	87.11044	37.94602	0.712154	0.171914
October	196.3	173.4015	88.34806	2.091224	5.675521
November	59.1	87.12942	147.5285	1.860794	2.503278
December	9.4	21.75032	232.1668	2.365634	4.616378

From table 1 it was observed that there is a significant variation in mean of monthly rainfall received in Ganjam district. It received maximum average monthly rainfall 272.7mm in the month of august while minimum average rainfall in the month of December 9.4mm. CV of rainfall is lowest in august while highest in December. It showed that more uniform rainfall is received during august month resulting in assured crop production and agricultural activities and other months need proper irrigation for crop production. The skewness data for monthly rainfall varied from 0.3 to 3.7. It showed positive skewness and shows the data are right skewed. Kurtosis of monthly rainfall varies from 0.1 to 3.6. April, June and July shows negative Kurtosis that means monthly rainfall data is flat i.e. rainfall distribution is almost same, while other months shows positive kurtosis. May month shows highest peak in rainfall distribution with kurtosis coefficient value 6.36.

Table 2: Statistical properties of Seasonal and annual rainfall of Ganjam district (1890-2019)

	mean	SD	CV	Skewness	Kurtosis
Monsoon	898.7	166.22	18.49	0.0	-0.4
Post monsoon	255.3	194.48	76.17	1.1	1.2
Winter	33.5	34.62	103.31	1.3	1.2
Summer	142.8	115.13	80.60	3.3	2.53
Annual	1330.3	297.89	22.39	0.64	0.28

Table 2 shows that there is a significant variation in mean of seasonal and rainfall received in Ganjam district. It received maximum average seasonal rainfall 898.7mm in the monsoon season (June to September) while minimum average rainfall 33.5mm in winter season (November to December). CV of rainfall is lowest in the season of monsoon while highest in winter. It showed that more uniform rainfall is received during monsoon resulting in assured highest agricultural activities and other months need proper irrigation for crop production. The skewness data for seasonal rainfall varied from 0.0 to 3.3. It showed positive skewness and shows the data are right skewed. Kurtosis of seasonal rainfall varies from -0.4 to 2.56. Monsoon shows negative Kurtosis that means monthly rainfall data is flat while other seasons positive kurtosis. Summer season shows highest peak in rainfall distribution with 2.58 kurtosis that means the rainfall distribution is very peak. Annual average rainfall is 1330.3 mm. annual rainfall distribution is positive skewed and minimum CV resulting moderate variation in rainfall distribution in different years.


January
70
60
50
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20
10
0
January
1990
1995
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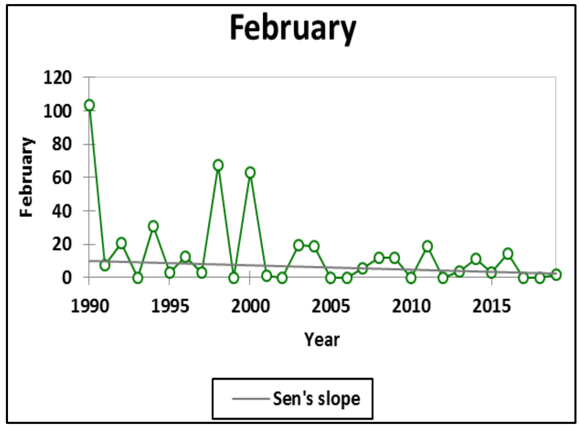
2005
2010
2015
Year
Sen's slope


February
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20
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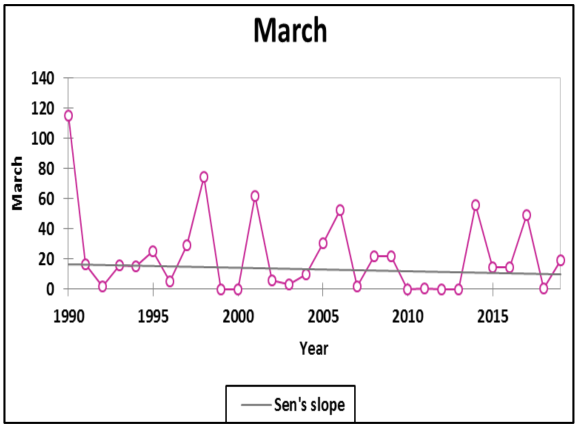
February
1990
1995
2000
2005
2010
2015
Year
Sen's slope


March
140
120
100
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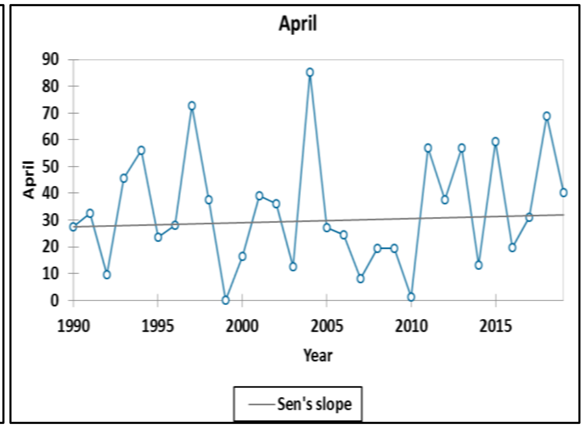
40
20
0
March
1990
1995
2000
2005
2010
2015
Year
Sen's slope


April
90
80
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0
April
1990
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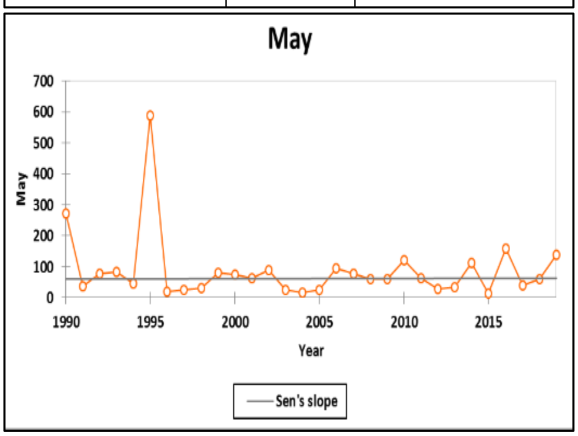
2015
Year
Sen's slope


May
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600
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400
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200
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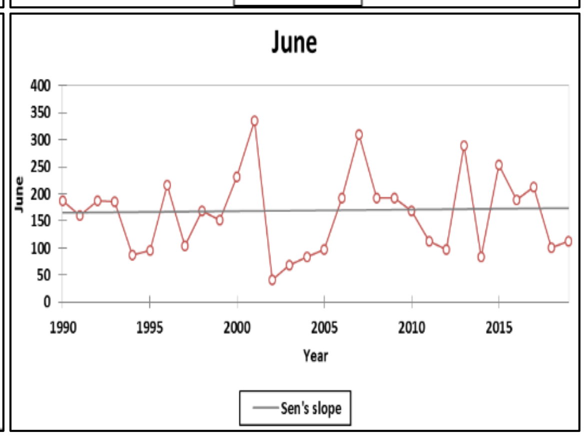
0
May
1990
1995
2000
2005
2010
2015
Year
Sen's slope


June
400
350
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250
200
150
100
50
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June
1990
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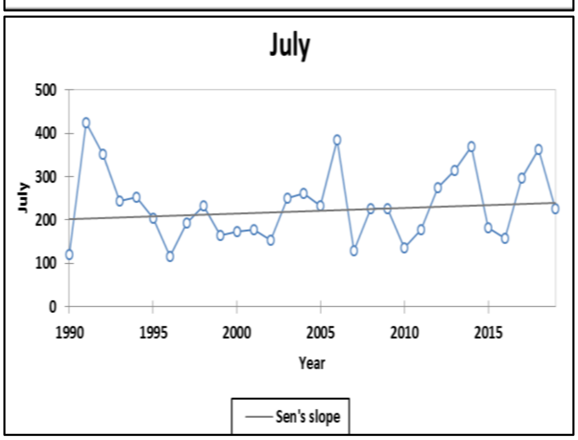
2005
2010
2015
Year
Sen's slope


July
500
400
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200
100
0
July
1990
1995
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2005
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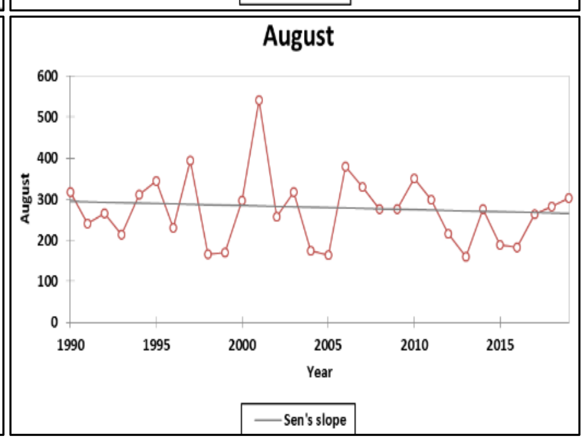
2015
Year
Sen's slope


August
600
500
400
300
200
100
0
August
1990
1995
2000
2005
2010
2015
Year
Sen's slope

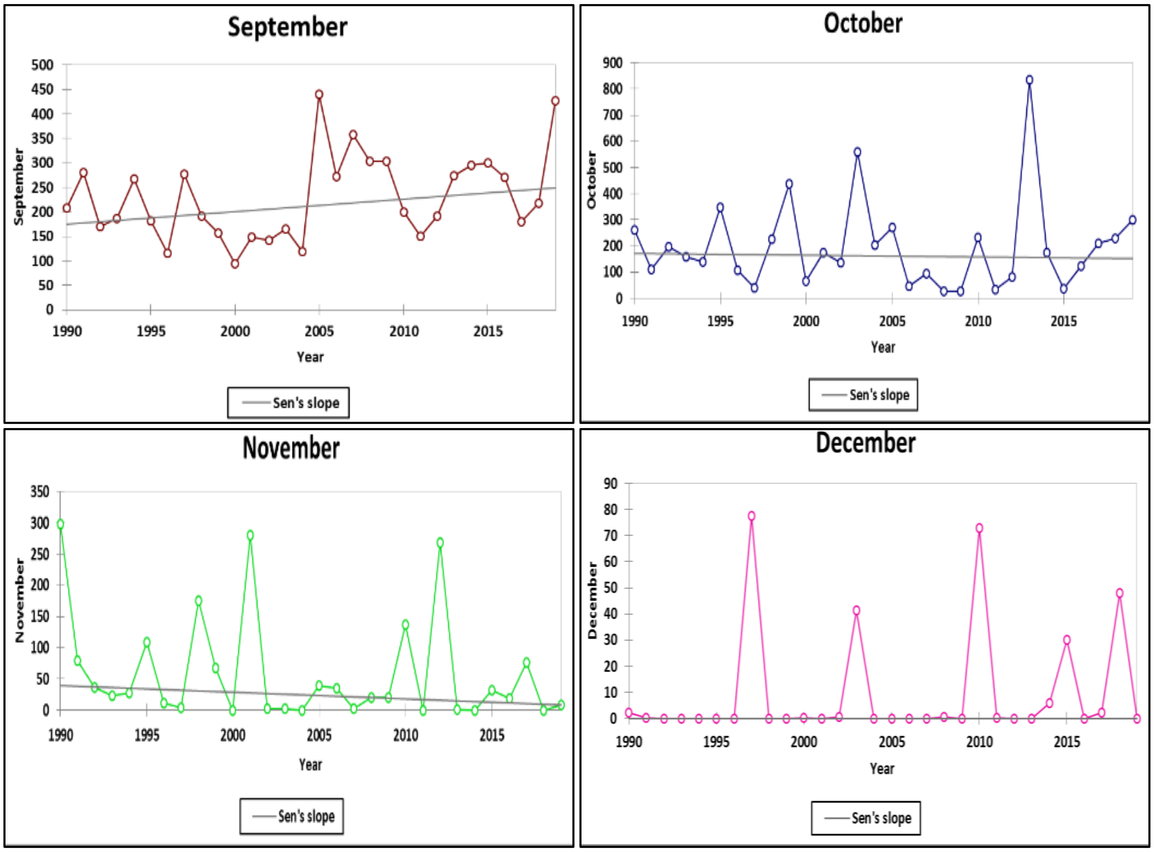
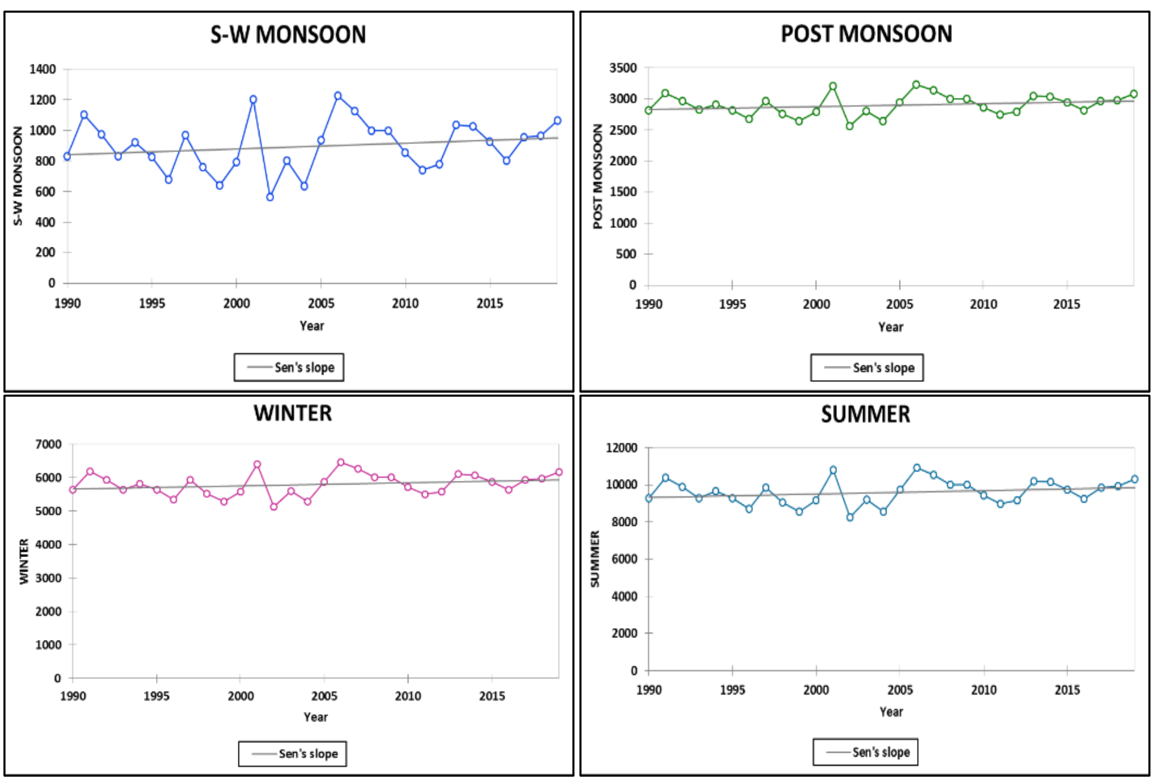


Fig 1: Trend of monthly rainfall

Figure 1 shows the monthly rainfall trend with Sen's slope. In this figure April, May, Jun, July, and September shows positive trend of rainfall means increasing rainfall while February, March, October and November shows negative rainfall trend with reducing rainfall amount. December month shows no trend in rainfall.



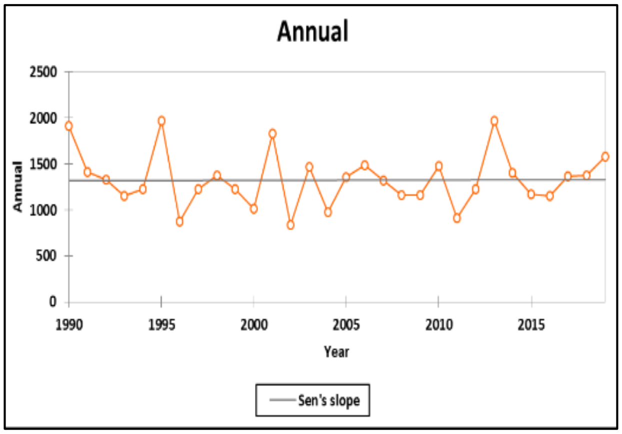


Fig 2: Trend of Seasonal and annual rainfall

In figure 2 represents the seasonal and annual rainfall trend with Sen's slope. Here all the seasons shows positive trend which assured that the rainfall is increasing trend. Annual rainfall also shows positive slope which is suitable for agricultural production .

Table 3: Statistical Analysis of Monthly Rainfall data along with Mann-Kendall Trend and Sen's Slope

Series\Test	Kendall's tau	p-value	Sen's slope	Trend
January	-0.051	0.709	0.000	No trend
February	-0.264	*0.045**	*-0.280*	Negative trend
March	-0.093	0.474	*-0.190*	Negative trend
April	0.076	0.556	0.160	Positive trend
May	0.009	0.943	0.058	Positive trend
June	0.046	0.721	0.266	Positive trend
July	0.074	*0.043**	1.284	Positive trend
August	-0.064	0.617	-1.002	Negative trend
September	0.189	*0.034**	2.559	Positive trend
October	-0.032	0.803	-0.726	Negative trend
November	-0.246	*0.048**	-1.085	Negative trend
December	0.138	0.336	0.000	No trend
S-W monsoon	0.106	*0.035**	3.753	Positive trend
Post monsoon	0.149	0.256	4.753	Positive trend
Winter	0.149	0.256	9.506	Positive trend
Summer	0.126	0.339	8.012	Positive trend
Annual	0.005	0.972	0.112	Positive trend

(* shows significance at 5% level of significance)

The variation in rainfall data (trend) on monthly basis is calculated individually for each month using Mann-Kendall statistically method and magnitude of slope is calculated with Sen's slope estimator as represented in table 3. It was analysed that there is significant changes in monthly rainfall data mean some of the months showed increasing (upward) trend and some showed decreasing trends. Five months (April, May, Jun, July, and Sept) give positive values of Z– Statistics which represent rising trend while other months (Feb, Mar, Oct, and Nov) represent falling trend as shown in Figure 1.February and November month shows negative trend with 5% level of significance which means the rainfall is decreasing, but July and September month shows positive trend with 5%level of significance. January and December month shows no trend in rainfall distribution. The estimated Sen's Slope (Q) was also calculated for each month separately and the month April, May, Jun, July, and Sept give increasing slope magnitude and the month of April, June, and July showed non-significant decreasing trend. But the month of January and December showed no change in Sen's Slope magnitude as shown in table. All the seasonal and annual rainfall data shows positive trend and gives increasing slope magnitude but South west monsoon rainfall shows positive trend with significance with 5% level of significance.

Conclusion

The results of the study depicted that there is substantial year to year and season to season variability in rainfall pattern and rainfall pattern is generally erratic in nature. The statistical results of tests indicated that in some months there's an increasing trend while in another months decreasing trend of precipitation. Individually five months (April, May, Jun, July, and Sept) represent increasing trend while the other four months (Feb, Mar, Oct, and Nov) represent a decreasing trend, and December month shows no trend. The trend looks predominantly positive (increasing), both at the annual and seasonal scale. The monthly analysis indicated that the months of July and September give significant increasing trend due to the positive value of both Z and Q statistics while April, May, and Jun showed a non-significant increasing trend. The month of February and November gives a giant decreasing trend because of the negative value of Z and Q statistics and so the month of April gives a non-significant decreasing trend. The trend of whole data on annual basis showed a positive increasing trend. The statistical analysis of whole series data indicated that the common annual rainfall of study is 1331.8 mm with maximum average annual is 1963.7 mm and thus the minimum average annual amount of rainfall is 866 mm also the value of the standard deviation of rainfall data depicted that there is a decent fluctuation in rainfall, about 70 the amount of rainfall occurs within the months of monsoon season also the months of July and August give the utmost amount of rainfall while the months of November and December provides a minimum amount of rainfall. Rainfall is that the foremost vital agro-climatic variable that determines the cropping system and overall agricultural productivity in rainfed areas of Southern Odisha and this increasing trend of rainfall on an annual and seasonal basis are used for better planning of water resources development and management schemes also as conservation of soil moisture in Southern Odisha.

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