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RESEARCH ARTICLE

RAINFALL TREND ANALYSIS OF BAITARANI RIVER SUB-BASIN, ODISHA.

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Abstract

The present paper is an attempt to analyze rainfall trend of Baitarani River (Odisha) for a period of 42 years (1971-2012). The trend in rainfall data on annual, seasonal and monthly basis are examined through Mann Kendall Test and Sen's Estimator of Slope. There is an overall positive trend in the annual rainfall but there are variations in terms of seasonal and monthly rainfall. There is a slightly increasing trend in the annual rainfall of Baitarani River Sub-Basin with an annual change of 7.23 mm/year statistically significant at 90% confidence level. Month of May and June shows positive trend at 90% confidence level. Annual rainfall shows a variation of 18.73%, while seasonal analysis shows a variation of 21.65%, 80.38% and 61.23% for Monsoon, Post-Monsoon and Pre-Monsoon respectively. March has the maximum variation of 220.6% while July has the least variation of 30.85%.

Introduction:-

Rainfall generate streamflow which is an important variable in any hydrological studies. Due to the existence of wide scale variations in the magnitude and intensity of rainfall both spatially and temporally, it leads to different kinds of hydrological problems like floods and droughts. It seems a sheer necessity that in any hydrological assessment of a basin, one must look into the prevailing climatic condition especially the rainfall pattern of the region. Maurya et al. (2016) have analyzed variability for Middle Tapi Basin using four methods namely Mann Kendall test, Sen's estimator of Slope, Innovative trend analysis and Rainfall variability index developed by L'Hote et al., 2002. Statistical assessment of rainfall trend and variability using Mann Kendall and Sen's slope in North-eastern Algeria is studied by Merniz et al. (2019). Linear Regression Model to examine the variability, trend and predict the rainfall patterns was studied by Rahman, 2017. In a study on temporal analysis of Kerala for a period of 141 years, the result showed that there is a decreasing trend in monsoon while there is increasing trend in the post monsoon and pre-monsoon period (Thomas et al., 2016). On the other hand, rainfall analysis of North-eastern India from 1871 to 2008 does not show any apparent and clear trend though seasonal variations are recorded (Jain et al., 2013). It is a known fact that any changes in climatic parameters can affect other component of the system and on socio-economic variables. Most importantly, rainfall variability affects the runoff characteristics of a region. The severity of the consequences of climatic variability on water resources is well studied by Kelkar et al. (2008) in their vulnerability and adaptation studies of Uttarakhand. Gosain et al. (2006) found that the severity of droughts and intensity of floods in various part of the subcontinent might get deteriorated. Collins et al. (2013) observed that the discharge in the Sutlej has declined by 32% between 1970s and 1990s indicating a substantial reduction in pre-monsoon precipitation during this interval. The correlation between rainfall variability and water supply can be observed through the study of Adetayo (2015) on his study area Ibadan South West L.G.A, Nigeria using descriptive

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statistics, correlation and regression analysis. Impact of rainfall variability on the yield of rice in Nigeria is well analysed by (Tiamiyu et al., 2015).Variability of rainfall and trend has been an important part of climatic studies to understand the long-term impact of climatic parameters on human and other components of the earth (Hasan et al., 2016; Nouaceur et al., 2017; Maurya et al., 2016). The effect of rainfall variability on flood occurrences and extremes are extensively studied and analysed (Arnaud et al. , 2002; Wulan, 2017; Clifford et al., 2019; Ochieng et al., 2017). The present paper is an attempt on rainfall trend analysis of Baitarani River Sub-Basin using Mann Kendall test and Sen's estimator of slope.

Material and Methods:-

Study Area

Present study is focused on the upper catchment of Baitarani River Sub-Basin which is located between 85°10'5''E to 86°20'30''E longitude and 22°15'N to 20°55'30''N latitude falling into the states of Odisha and Jharkhand.

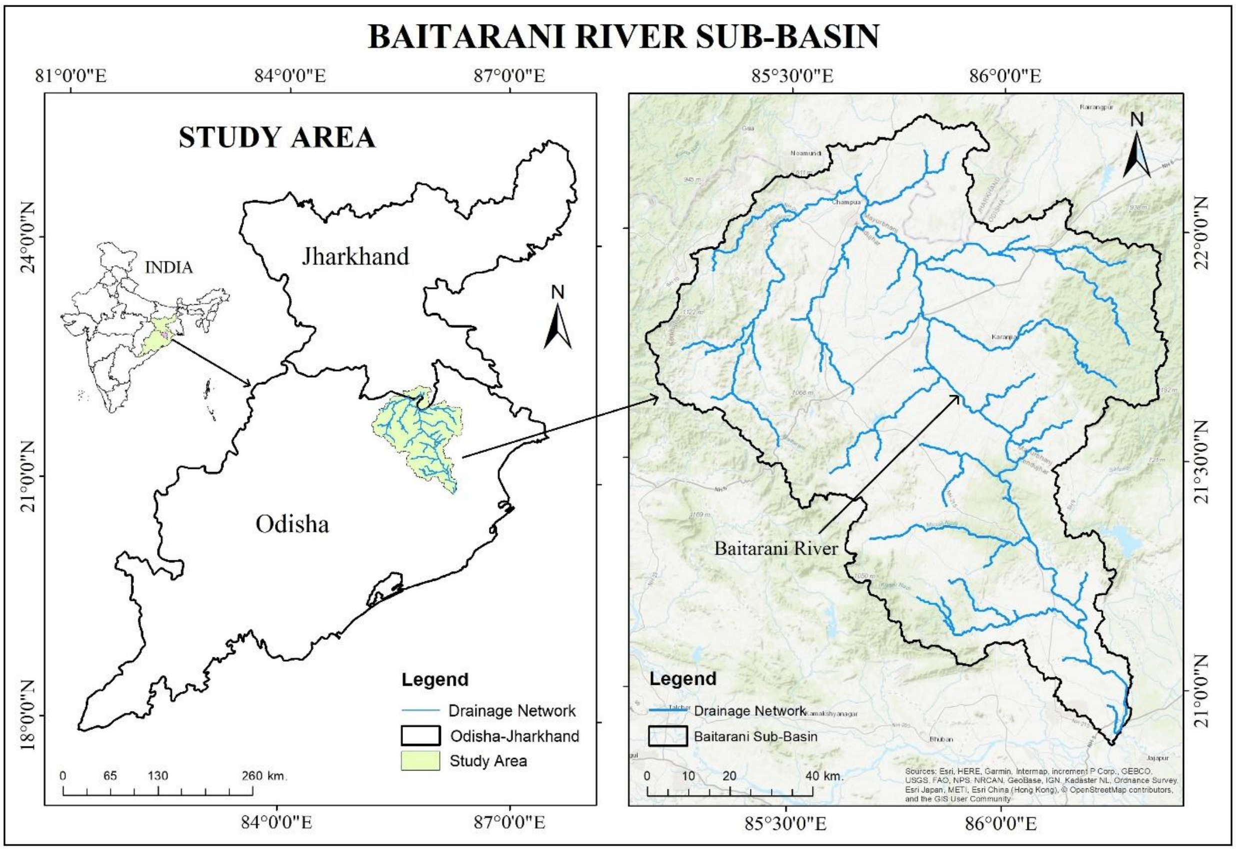

Figure 1:-Study Area

Database

Rainfall data for the time period of 1971-2012 is procured from Indian Meteorological Department, Pune and the Government of Odisha. Rainfall Stations includes Keonjhargarh, Baripada, Chandbali, Angul, Balasore and Chaibasa. The problem of missing values in the time series data set has been extrapolated using Station Average Method and Simple Average Method. Mean Areal Rainfall depth using Theisen Polygon method is calculated with the data obtained for all the stations. (The Detailed calculation is omitted in this article due to paucity of space).

Methodology:-

Mann Kendall Test

Mann Kendall Test is a non-parametric test to examine the presence of monotonic positive and negative trend in a given time series. It has been used by many researchers and meteorologists in their studies (Hasan et al., 2016; Adenodi, 2018; Maurya et al., 2016; Merniz et al., 2019; Kabanda, 2018; Kisi et al., 2014; Asfaw et al., 2018;

Afzal et al., 2011; Taxak et al., 2014; Guzha et al., 2018). The one assumption in this test is that the given data have no seasonality effect.

The Mann-Kendall Test can be applied to cases when the data values x_i of the time series can be assumed to obey the model

$$x_i = f(t_i) + \epsilon_i$$

Where $f(t_i)$ is a continuous monotonic increasing or decreasing function of time and the residuals ε_i can be assumed to be from the same distribution with zero mean. The variance of the distribution is assumed to be constant in time. The null hypothesis of no trend, H_o, i.e. the observations x_i are randomly ordered in time is to be tested against the alternative hypothesis, H_1, indicating the presence of an increasing or decreasing monotonic trend.
The Mann-Kendall Test statistic S is calculated using the formula

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k)$$

For data value more than 10 or at least 10, the normal approximation test is used. But if there are many tied values (i.e. equal values) in the time series, it may reduce the validity of the normal approximation when the number of data value is close to 10.

Firstly, the variance of S is computed by the following equation which account that the presence of a statistically significant trend is evaluated using the Z value.

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p - 1)(2t_p + 5)\right]$$

A positive or negative value of Z indicates an increasing or decreasing trend.

$$Z = \begin{cases} \frac{s-1}{\sqrt{VAR(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & if\ S < 0 \end{cases}$$

The statistic Z has a normal distribution. To test for either an upward or downward monotonic 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-α/$_2$, where Z_1-α/$_2$ is obtained from the standard normal cumulative distribution tables.

Sen's estimator of Slope

To estimate the true slope of an existing trend (as change per year) the Sen's estimator of slope is used. The Sen's method is used in cases where the trend can be assumed to be linear. This means that f(t) is equal to

$$f(t) = Qt + B$$

where Q is the slope and B is a constant.
To get the slope estimate *Q*, we first calculate the slopes of all data value pairs

$$Q_i = \frac{x_j - x_k}{j - k}$$

where $j>k$

There are *n* values x_j in the time series we get as many as $N = n(n-1)/2$ slope estimates $Q_{i.}$

The Sen's estimator of slope is the median of these *N* values of Q_i. The *N* values of Q_i are ranked from the smallest to the largest and the Sen's estimator is

$$Q = Q_{[(N+1)/2],} if\ N\ is\ odd$$

or

$$Q = \frac{1}{2}\left(Q_{[N/2]} + Q_{[(N+2)/2]}\right), if\ N\ is\ even$$

A 100(1-α) % two-sided confidence interval about the slope estimate is obtained by the non-parametric technique based on the normal distribution.

The confidence interval at two different confidence levels: α=0.01 and α=0.05, resulting in two different confidence intervals are computed as

$$C_a = Z_{1-\alpha/2}\sqrt{VAR(S)}$$

where *VAR(S)* is same as defined above and $Z_{1-\alpha/2}$ is obtained from the standard normal distribution.

Next $M_1 = (N - C_\alpha)/2$ and $M_2 = (N + C_\alpha)/2$ are computed. The lower and upper limits of the confidence interval, *Qmin* and *Qmax*, are the M_1^{th} largest and the $(M_2 + 1)^{th}$ largest of the N ordered slope estimates *Qi*. If M_1 is not a whole number the lower limit is interpolated. Correspondingly, if M_2 is not a whole number the upper limit is interpolated.

To obtain an estimate of B, the *n* values of differences $x_i - Q_i$ are calculated. The median of these values gives an estimate of B.

Results and Discussion:-

Trend Analysis

The result of the Mann Kendall test and Sen's Slope is given in table 1.

Period of Rainfall season/months	**Z value**	**Observation at 0.05 confidence level (Z critical=1.96)**	**Observation at 0.10 confidence level (Z critical=1.65)**	**Significance level**	**Sen's Slope (mm/year)**
Total Annual	1.669	No trend	Positive trend	Statistically significant at 0.10 level.	**7.23***
Monsoon	1.30	No trend	No trend	Insignificant	3.86
Post-monsoon	0.672	No trend	No trend	Insignificant	0.35
Pre-Monsoon Season	1.32	No trend	No Trend	Insignificant	1.29
January	0.564	No trend	No trend	Insignificant	0
February	1.136	No trend	No trend	Insignificant	-0.13
March	0.119	No trend	No trend	Insignificant	0.02
April	0.466	No trend	No trend	Insignificant	0.27
May	1.864	No trend	Positive trend	Statistically significant at 0.10 level	**1.16***
June	1.777	No trend	Positive trend	Statistically significant at 0.10 level	**2.29***
July	0.282	No trend	No trend	Insignificant	0.25
August	0.954	No trend	No trend	Insignificant	-1.40
September	0.412	No trend	No trend	Insignificant	0.59
October	0.249	No trend	No trend	Insignificant	-0.24
November	1.084	No trend	No trend	Insignificant	0.15
December	0.39	No trend	No trend	Insignificant	0

*Bold values indicate statistically significant at 90% confidence level (Sen's estimator of slope)

Table 1:-Result of Mann Kendall Test of Rainfall dataset

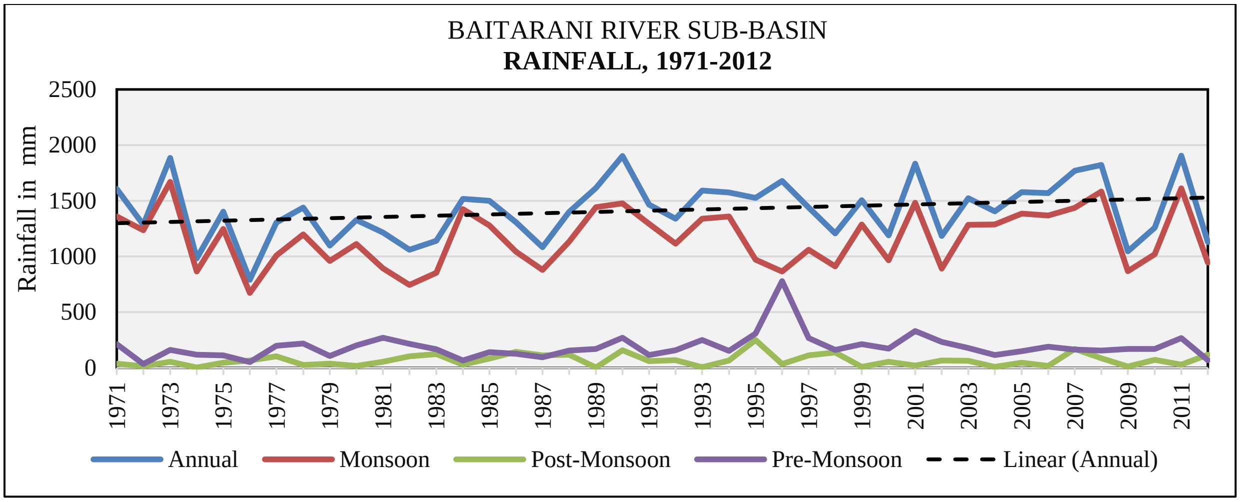

Figure 2:-Trend in Rainfall, Baitarani River Sub-Basin, 1971-2012

From the analysis, it has been observed that there is a no statistically significant increasing or decreasing trend in the total annual rainfall of the Baitarani River Sub-Basin as observed at 95% confidence level. However, there is a positive trend significant at 90% confidence level. The significance of the test is examined at 0.05 and 0.10 confidence level. Seasonal analysis of the trend shows that there is no trend in terms of monsoon, post-monsoon and pre-monsoon season which is statistically significant. Monthly analysis shows no trend in most of the months but there is positive trend in terms of May and June which is statistically significant at 90% confidence level respectively.

Rainfall Variations

The calculation of coefficient of variations of months and seasons are tabulated in table 2. The highest variation is found in March with a coefficient of variation of 220.71% followed by December (190.78%), November (147.89%), January (140.90%) and February (132.53%) indicating high variation during winter and spring season. The lowest variation is found during July (30.85%) followed by August (36.19%) and September (44.75%) indicating less variation during the rainy season.

MONTH/ SEASON	Mean (1971-2012) (in millimetres)	Standard Deviation (in millimetres)	Percentage share to the Annual Rainfall (%)	Coefficient of Variation (%)
January	14.2	20	1.00	140.8
February	20.9	27.6	1.47	132.1
March	46.6	102.8	3.30	220.6
April	46.0	34.8	3.25	75.7
May	93.2	51.9	6.59	55.7
June	231.6	123.5	16.38	53.3
July	268.3	82.7	18.97	30.8
August	315.1	113.6	22.21	36.1
September	239.2	107	16.91	44.7
October	108.7	98.5	7.69	90.6
November	25.0	36.9	1.76	147.6
December	6.4	12.1	0.45	189.1
Annual	1414.37	265	100	18.7
Monsoon	1162.10	251.61	82.16	21.65
Post-Monsoon	66.40	53.3	4.69	80.3
Pre-Monsoon	185.89	61.23	13.14	61.23

Table 2:-Variations in Rainfall, Baitarani River Sub-Basin, 1971-2012

Baitarani River Sub-Basin received a fair amount of precipitation annually over 1400-1600 mm. Due to its geographical location, the Sub-Basin received rainfall almost all throughout the year. Only January and December have no rainfall in some years. There are records of untimely high rainfall during January and December. Most of the precipitation is received during June, July, August, September and October. The maximum rainfall is received during August followed by July, September, June and October. From the analysis above, it is found that there is a slightly increasing trend in the annual rainfall of Baitarani River Sub-Basin based on the period of 1971-2012 which is statistically significant at 90% confidence level. Sen's slope analysis shows an annual change of 7.23 mm per year. The finding is supported by another study by Mitra et al. (2014) where they found that the average annual rainfall at the Baitarani River basin has increased by 8.8 mm per year in the last 30 years (1974-2004) which has resulted to an increase in streamflow in the river basin. If we look at seasonal basis, there is no significant trend observed in all the seasons. Similarly, in the case of monthly rainfall, except for May (Sen's slope =1.16 mm/year) and June (Sen's slope = 2.29 mm/year) all the other months does not show any significant increasing or decreasing trend as such. Thus, we can say that precipitation has increased during May-June which influence the overall annual trend. The linear trendline shows increasing trend in most of the study period despite statistically insignificant. This may be attributed to the effect of especially unusual high rainfall events in the recent years. For instance, in 2008, June received an exceptional peak of 745.684 mm as compared to the average 268.37mm monthly rainfall. Similarly, 1996 received a rainfall of 680.34 mm during the month of March alone. Such kind of extreme events seems to be frequent in the recent periods consequently affecting the trendline.

Conclusion:-

In the present study, rainfall trend is examined through Mann Kendall Test. While there is an overall positive trend in annual rainfall with an annual change of 7.23 mm/year (Sen's Slope), there is no such trend in case of the seasons. May and June show a positive trend while the rest of the month shows no such trend. Variations are maximum in case of post-monsoon rainfall and minimum in case of annual rainfall. March has the maximum rainfall variation and July has the minimum variations.

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