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The Trend Analysis Of Rainfall In The Wainganga River Basin, India

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ABSTRACT
Daily rainfall with a high resolution of 0.25˚X0.25˚ IMD gridded data during 1913-2013 (101 Years) for Wainganga river basin (100 grids) included in Maharashtra and Madhya Pradesh in India is analyzed in the present study. For the analysis, daily data is converted to annual, annual maximum, monthly and monthly maximum rainfall values. This data has been checked for homogeneity and its trend for the above period. Homogeneity of the data was checked by Von-Neumen test, SNHT, Buishand's test and Pettitt's test. Trend analysis is carried out by Non parametric tests, those are; Mann-Kendall test, Sen's slope estimator and also with Sen's Innovative trend analysis. The analysis shows decreasing trend for monthly and annual rainfall values over the basin area. However, for maximum values of the rainfall in monsoon period, the trend is found to be increasing in nature about 1280 mm of annual rainfall with return period of 2 years and maximum daily rainfall at 250 mm with return period of 5 years, indicating the peak events are happening at monthly as well as annual frequency. Study reveals that the intensity of rainfall for shorter periods is increased in the basin, which will lead to increase in flood events in future.

KEYWORDS - Frequency analysis, Homogeneity tests, Innovation Trend analysis, Non Parametric tests**.**

I INTRODUCTION

Rainfall varies spatially and temporally and is one of the most relevant characteristics in the hydrological cycle. The surface climatic variations affect the rainfall pattern. The changing precipitation pattern, and its impact on surface water resources, is an important climatic problem facing society today. Rainfall trend analysis is an aspect of analyzing the past data to predict the future rainfall pattern. Basistha et al., 2009[1] studied that there is a sudden shift in the rainfall trend of Himalayan regions in India. Taxak et al., 2014[2] found out that 15 out of 22 basins in India are experiencing decreasing trend in rainfall. The trend analysis of rainfall may help in management and planning of water resources projects. So a similar analysis was carried out for calculating rainfall trend of Wainganga basin, India to help in river management and planning.

In rainfall, change detection can be by two statistical techniques, they are non-parametric and linear models. The non-parametric model such as Sen's slope estimator and Mann-Kendall test to detect statistical significance and linear model such as least

square regression to determine the magnitude of the trend (Timbadiya et al., 2013[3], Meena et al., 2015[4], Sabyasachi Swain et al., 2015[5]). The present study focuses on trend analysis of annual average rainfall, monthly average rainfall and extreme rainfall values in Wainganga River Basin, which is sub basin of Godavari River, India.

II STUDY AREA

The study is carried out for the Wainganga River basin of India, which is a sub-basin of the Godavari River, and lies approximately between 19˚45'N to 22˚45'N latitudes and between 78˚00'E and 81˚00'E longitudes. It has a total area of about 51,412 sq·km [2], occupied 16% of the total geographical area of the Godavari River basin and 1.6% of the total area of India.

The elevation ranges from 144m to 1208m above mean sea level over the entire Wainganga basin . The climatology of the study area can be outlined as three dominant seasons via summer (March-May), monsoon (June-October) and winter (November-February).Temperature hits up to 47˚C during summer and minimum temperature during winter varies from 7˚C to 13˚C. The south-west monsoon owes major part of rainfall of the basin. Wainganga basin lies in the medium rainfall zone of 90cm to 160cm. It is observed that the basin experiences a contrasting climatic behavior against the whole state of Maharashtra. Rainfall rate is progressively increasing devising flood as a major problem of the area. Index map of the study area is given in Fig.1

Fig.1 Index map of Wainganga basin, India

III METHODOLOGY

The IMD 0.25˚X0.25˚gridded rainfall data was converted to monthly, monthly maximum, annual and annual maximum. Homogeneity of the data is checked by various methods and trend of all rainfall values was analyzed by using non-parametric tests and compared with an Innovative trend method proposed by Sen (2010)[6]. And frequency analyzed over entire time series carried out by Gumbel's distribution (Extreme value type I).

3.1 Process of the Data

High resolution rainfall data used to get more accuracy in the rainfall pattern, it may help in the managing and planning of water resources projects. In present study, the data collected from IMD, checked for homogeneity, analyzed the trend of rainfall and frequency to get magnitude of the maximum rainfall in the Wainganga river basin, India.

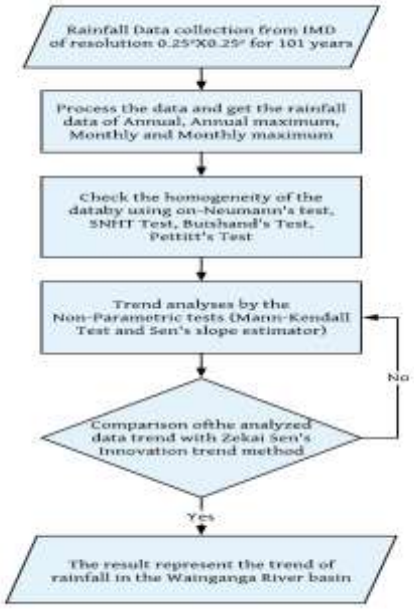

Fig.2 Flow chart to find the trend analysis of rainfall

3.1.1 Mann-Kendall Test

The most commonly used non parametric test to find the trend of a time series. In this method the first value of the data assumed to be there is no trend in the study period it means null hypothesis (H0) and the alternative hypothesis (Ha) is there trend in the study period. Based on Z value we can find the trend in the series.

The equations used in Mann-Kendall test are

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(X_j - X_i) \text{ ---------- (1)}$$

Where, X_i and X_j are the rainfall values representing the years i and j(j=i+1)

$$\operatorname{sgn}(Y) = \begin{cases} +1, \text{if } Y > 0 \\ 0, \text{ if } Y = 0 \\ -1, \text{if } Y < 0 \end{cases} \text{ ----------(2)}$$

Where $Y=(X_j - X_i)$

If n > 8 then S follows approximately Normal Distribution with mean E[S] = 0 and the variance V(s) is given by,

$$V(s) = \frac{n(n-1)(2n+5) - \sum ti(ti-1)(2ti+5)}{18} \text{ ---------(3)}$$

Where ti is number of ties in the sample analysis.

$$Z = \begin{cases} \frac{S-1}{\sqrt{\sigma 2}}, & \text{If } S > 0 \\ 0, \text{If } S = 0 \\ \frac{S+1}{\sqrt{\sigma 2}}, \text{If } S < 0 \end{cases} \text{ ----------(4)}$$

Here Z follows the Standard normal distribution. compare this Z (Z=1.96) value at 95 % probability level and 5% significance level. If the obtained values in study are higher than 1.96 it indicates the trend is increasing, less than 1.96 it indicates decreasing trend otherwise there is no trend in the time series.

3.1.2 Sen's Slope Estimator

It is a non parametric test linear method. The slope of the trend line is upwards it indicating increasing trend and downward slope is indicating decreasing trend in the time series.

The slope can be given by Type equation here.

$$Si = \frac{X_j - X_i}{j - i} \text{ ----------(5)}$$

Where X_i and X_j are data values at time i and j.

The median of n values of Si is represented as Sen's slope estimator's slope is given by

$$Qi = \begin{cases} S_{\frac{n+1}{2}} \text{ if n is odd} \\ \frac{1}{2}\left(S_{\frac{n}{2}} + S_{\frac{n+2}{2}}\right) \text{ if n is even} \end{cases} \text{ ---------(6)}$$

After calculating Qi for testing Qmedian is computed by two tail test at 95% confidence level and 5% significance level then the true slope is compared if obtained slope is upwards the trend is

increasing the slope is downwards it is decreasing trend.

3.1.3 Sen's (2010) Innovative Trend Method

In this method the rainfall data has been divided into two halves and sort it in ascending order. Plot the graph in first quadrant of Cartesian system between first half series on abscissa and second half series on ordinate. Make the graph in square shape and draw a Straight line at an angle 45˚ with positive horizontal from origin. The trend can identify with the help of 45˚ straight line.

The cluster/group of points lies upper triangle and the cluster lies lower triangle indicates increasing and decreasing trend respectively. The points lies upper portion of upper triangle and lower portion of lower triangle indicates increasing trend, and the points lies lower portion of upper triangle and upper portion of lower triangle indicates decreasing in trend. With help of this method predict the trend of rainfall and runoff. To analyses the data in this method need not require more assumption.(Sen 2012)[6].

The Internal trend of time series can be explained by 45˚ line as low, medium and high. The cluster is closer to 1:1 slope line the trend magnitude is weak. If the cluster appear along 45˚ line then there is monotonic trend in the time series otherwise there is no trend or various trend.

IV RESULTS

The data was checked for homogeneity by SNHT, Von-Neumann's test, Pettit's test and Buishand's test, The data is homogeneous and found the trend by the Mann-Kendall method, Sen's slope estimator and compared with the help of Innovative trend method by Sen (2012). The increasing trend is observed for maximum annual rainfall, for the annual rainfall, trend is decreasing. Also, overall trend is found to be increasing in monsoon months for maximum values (For October month there is no trend), in remaining months it is indicating decreasing (Except Jan month increasing trend and for November, December there is no trend), monthly rainfall for all months, the trend is decreasing (Except December month trend is opposite).

The frequency analyzed for particular return periods to find the magnitude of the maximum rainfall in the basin, it reveals that as the frequency decreases, the probable maximum rainfall is more about 1280mm annual rainfall with 2 years return period and 250 mm annual maximum rainfall with 5 years return period. About 2080 mm of annual rainfall and 402 mm of annual maximum will occur in 100 years.

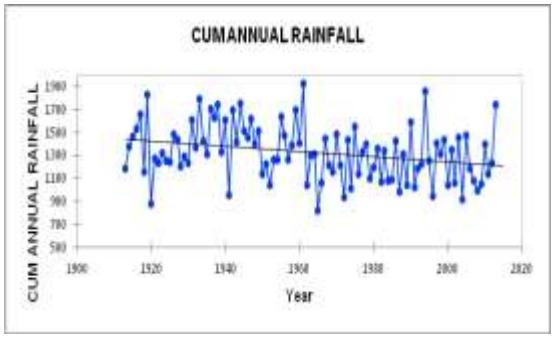

Fig.3 Time series graph for annual rainfall data showing negative trend

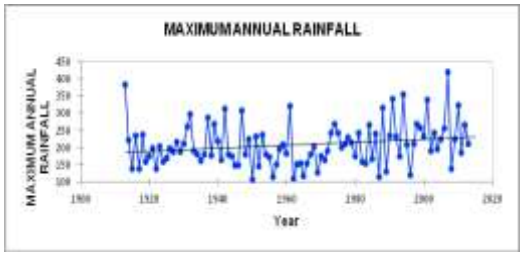

Fig.4 Time series graph for annual maximum rainfall data showing positive trend

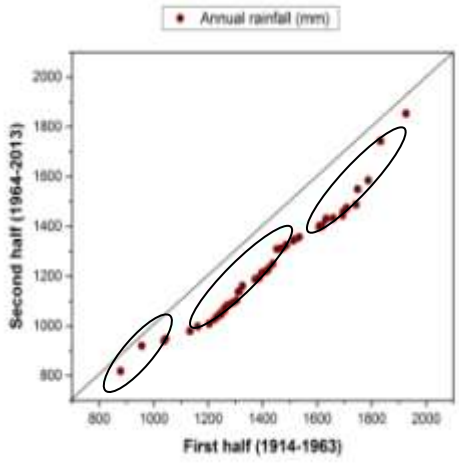

Fig.5 Innovative trend of annual rainfall values showing cluster in lower triangle i.e. decreasing in trend.

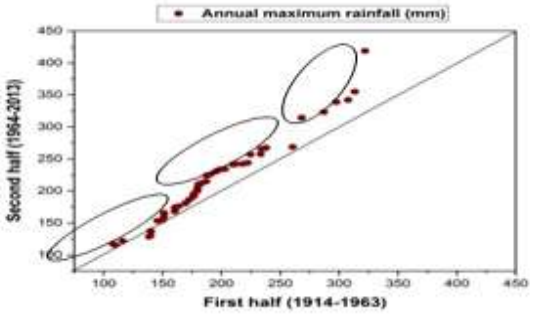

Fig.6 Innovative trend for annual maximum rainfall values showing cluster in upper triangle i.e. increasing trend.

From Fig.3 Annual rainfall time series plot forecasting linear line indicates the slope is decreasing and from Figure5. the cluster points lies lower triangle, it reveals the annual rainfall trend is decreasing. Likewise figure 4 and 6 are showing increasing trend for annual maximum rainfall values.

Table.1 The magnitude of daily maximum rainfall occurred in particular return period.

The magnitude of daily maximum rainfall occurred in particular return period (Year)					
Return Period(Year)	**Mean**	**K_T**	**SD**	**X_T**	**Rainfall(mm)**
2	8.686489	-0.164	2.580189	8.263338	198.3201
5	8.686489	0.719	2.580189	10.54165	252.9995
10	8.686489	1.305	2.580189	12.05364	289.2873
50	8.686489	2.592	2.580189	15.37434	368.9842
100	8.686489	3.137	2.580189	16.78054	402.733

Table. 2 The maximum magnitude of annual rainfall occurred in particular return period.

The magnitude of annual rainfall occurred in particular. return period (Year)					
Return Period(Year)	**Mean**	**K_T**	**SD**	**X_T**	**Rainfall(mm)**
2	55.19345	-0.164	9.996624	53.554	1285.296
5	55.19345	0.719	9.996624	62.38102	1497.144
10	55.19345	1.305	9.996624	68.23904	1637.737
50	55.19345	2.592	9.996624	81.10469	1946.513
100	55.19345	3.137	9.996624	86.55285	2077.268

V CONCLUSION

The long-term trend analysis of Wainganga basin during a period of 101 years have been investigated using Mann-Kendall method, Sen's slope estimator and Innovative trend method. The study concluded that the rainfall trend for the maximum annual and maximum monthly values for monsoon period are showing increasing trend (except for October month). For annual and monthly rainfall data showing decreasing trend but for August there is no trend. The frequency analyzed over entire time series, showing as return period increases the magnitude of rainfall increases in the basin. In shorter period the rainfall is more, it indicates flood will happen in future.

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