Climate Change Impact on Annual and Monthly Rainfall on Bhadar River Basin, India using Linear Regression and Innovative Trend Method

Geeta S. Joshi, Dhaven Rughani, Vijay M. Rana

Abstract*: Bhadar is one of the major rivers of Kathaiwar (Saurashtra) peninsula in Gujarat, India. It originates near Vaddi (Aniali Village) about 26 km north – west of Jasdan in Rajkot district of the state of Gujarat, India at an elevation of 261 m above mean sea level. Impact assessment of climate change over Bhadar river basin is carried out using two statistical methods of Trend Analysis i.e. linear Regression, and Innovative Trend method. Effect of climate change on annual rainfall and monthly rainfall are studied. Results show that there is an overall increase in annual rainfall trend in Bhadar river basin/catchment area at all stations except one station. The results for monthly rainfall show that the rainfall in the month of July and September shows increasing trend at all stations. The results obtained using Linear Regression and Innovative Trend method are found to be consistent.

***Keywords*: Rainfall, Bhadar River Basin, Linear Regression, Innovative Trend Method, Climate Change**

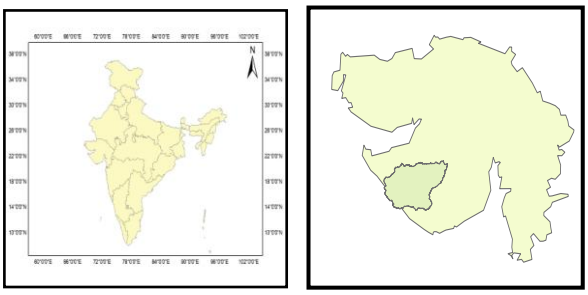
I. INTRODUCTION

The change in the climate is observed globally. The climate change is continuously occurring phenomena observed over the world, however the impact of the climate change varies region to region. The impacts of climate change are observed in the form rising of mean sea level, rise in temperature, melting of ice, increase or decrease in rainfall, occurrences of extreme events such as heavy rainfall or flood. It is necessary to assess the impact of climate change in a river basin area because rainfall in this area drains into river and causing the intense flood.

Precipitation is one of the most important climatic variable affecting both the spatial and temporal patterns of water resources [1]. Precipitation is an important element for the functionality of the Earth's system. However, this system is vulnerable to long-term temperature fluctuations, more commonly termed as climate change. The analysis of changes in meteorological variables such as precipitation, humidity, wind, temperature, etc. represent an important role in climate change impact assessment. Many research works have been done on detecting possible climate trends and changes across the world. However, most of these studies have been centred on analysing temperature and precipitation only. Analysing the long-term trends and variability of rainfall is very important for sustainable water resources management [2], [3]. To identify and understand the impacts of climate change on the atmospheric - hydrologic cycle, flood situation, agriculture; investigations of the characteristics of variations in regional temperature and precipitation are important [4]. And this information can directly be used by the hydrologic impact models for long-term productivity analysis [5][6]. It is well realized that natural climate variability like decadal changes in circulation and human induced changes such as land cover and emissions of greenhouse gases alter the rainfall patterns [7]. It is very important to identify the historical changes in the mean annual precipitation but even in the absence of changes in annual total precipitation, changes in the seasonal precipitation greatly affect partitioning of water into runoff, evapotranspiration and infiltration and thus flood forecasting, stream discharge and ecosystem responses [8][9].

The attempt is made in this study to assess the impact of climate change on annual and monthly rainfall in the Bhadar river basin, Gujarat, India. The area that this basin covers is 7094 km^2. The total length of this river is 198 km. The basin lies between geographical co-ordinates of 21^0 25' and 22^0 10' north latitudes and 69^0 45' and 71^0 20' east longitudes. The basin lies between geographical co-ordinates of 21^0 25' and 22^0 10' north latitudes and 69^0 45' and 71^0 20' east longitudes.

The map of the Bhadar river basin is constructed in Arc-GIS 10.3. The basin map of Bhadar River basin is shown in Figure 1.



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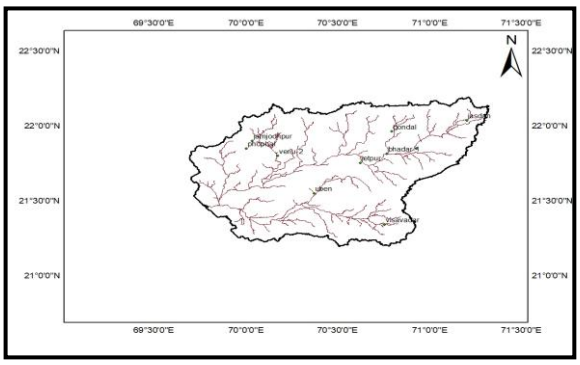

Fig. 1.Bhadar River Basin Map

II. DATA COLLECTION

A. Rainfall data

Daily rainfall data of 10 raingauge stations installed in a Bhadar river basin are available from state Water Data Centre (SWDC), Gujarat, and for 5 raingauge station from Indian Meteorological Department (IMD), India. Table 1 shows the details of these raingauge stations. There are total 15 raingauge stations distributed in the study area of 7094 sq. km. On an average, one raingauge station is covering 475 sq.km. This will provide good spatial distribution of the trend of annual and monthly rainfall over entire river basin area.

Table- I: Details of the raingauge stations (SWDC)

Sr. No.	Raingauge station		
	Name	*Data Length*	*Source*
1	Venu 2	1977-2012	SWDC
2	Phoaphal	1973-2012	SWDC
3	Kamadhiya	1982 – 2016	SWDC
4	Jepuer	1961 – 2016	SWDC
5	Gondal	1961 – 2016	SWDC
6	Jasadan	1981 – 2016	SWDC
7	Jamjodhpur	1962 – 2016	SWDC
8	Bhadar-1	1971 – 2012	SWDC
9	Uben	1962 – 2014	SWDC
10	Visavadar	1961 – 2016	SWDC
11	Dhoraji	1901 – 2011	IMD
12	Jasdan	1901 – 2012	IMD
13	Gondal	1901 – 2013	IMD
14	Jamkandorna	1960 – 2013	IMD
15	Ranavav	1960 – 2013	IMD

III. METHODOLOGY

This section describes the two statistical methods for trend analysis of annual rainfall and monthly rainfall i.e. Liner Regression method and Innovative Trend Method.

A. Linear Regression

Regression Analysis (LR) is a powerful statistical method that allows examining the relationship between two or more variables – in this case the relationship of annual rainfall with time (year). In this study, this method is employed to examine the influence of time (independent variables) on annual rainfall (dependent variable).

B. Innovative Trend Method

This sub-section presents a new methodology of Innovative Trend method (ITM) on the basis of sub-time series plots derived from a given time series on a Cartesian coordinate system [14]. In such a plot, trend free time series sub-series appear along the 45° straight-line. Increasing (decreasing) trends occupy upper (lower) triangular areas of the square area defined by the variation domain of the variable concerned.

C. Trend Detection of Annual rainfall and monthly rainfall

Using Linear Regression method, and Innovative Trend method, the trend (Positive/Negative) of annual rainfall and monthly rainfall at all raingauge stations within the study area have been identified. The results of the trend analysis for positive or negative trend of annual rainfall are compared.

IV. RESULTS

The results obtained from Linear Regression and Innovative Trend method are represented in this section. Fig.1 shows the result of the trend analysis of annual rainfall using linear regression at raingauge station Jetpur.

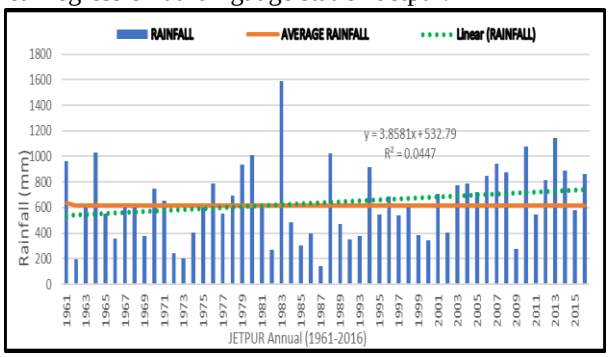

Fig. 1. Trend analysis of annual rainfall using Linear regression at station Jetpur.

The dotted green line shows the increasing trend of the annual rainfall over the data span.

Fig.2 shows the result of the trend analysis of annual rainfall using Innovative Trend method at station Jetpur

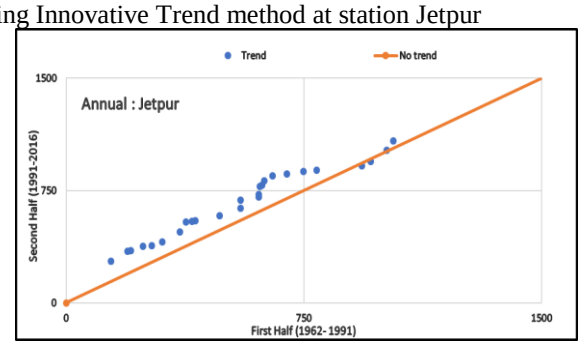

Fig. 2.Innovative Trend Method plot of annual rainfall at station Jetpur

From the Innovative trend plot for annual rainfall at station Jetpur, it is observed that the plot points lies in the upper triangular portion. It indicates increasing magnitude of annual rainfall in the later sub-series (1991-2016) of the total data span (1962-2016).

Thus, it is analyzed that the annual rainfall at station Jetpur shows positive (increasing) trend from LR method and ITM method both.

The results obtained at all other stations for the trend detection are summarized as shown in Table II.

Table- II: Trend Detection of annual rainfall using LR and ITA method

Sr. No.	Trend – positive (Increasing)/Negative (Reducing)		
	Name	*LR method*	*ITA method*
1	Venu 2	Positive	Positive
2	Phoaphal	Negative	Positive
3	Kamadhiya	Positive	Positive
4	Jepuer	Positive	Positive
5	Gondal	Positive	Positive
6	Jasadan	Positive	Positive
7	Jamjodhpur	Positive	Positive
8	Bhadar-1	Positive	Positive
9	Uben	Positive	Positive
10	Visavadar	Positive	Positive
11	Dhoraji	Positive	Positive
12	Jasdan	Positive	Positive
13	Gondal	Positive	Positive
14	Jamkandorna	Positive	Positive
15	Ranavav	Positive	Positive

Fig.3 shows the result of the trend analysis of monthly rainfall for the month of July using linear regression for raingauge station Jetpur.

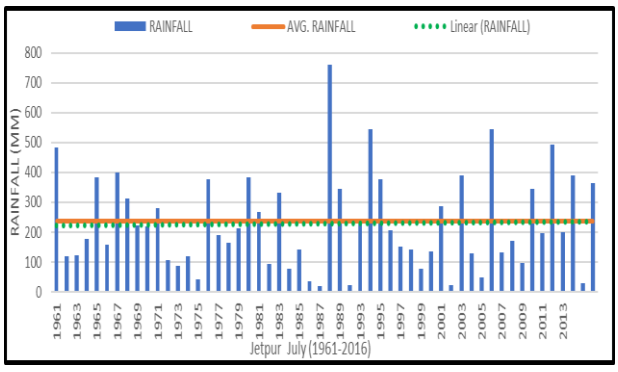

Fig. 3. Trend analysis of monthly rainfall using Linear regression at station Jetpur for the month of July. Fig. 3 shows increasing trend of the July month rainfall at station Jetpur.

Fig.4 shows the result of the trend analysis of monthly rainfall for the month of July using Innovative Trend Method at station Jetpur

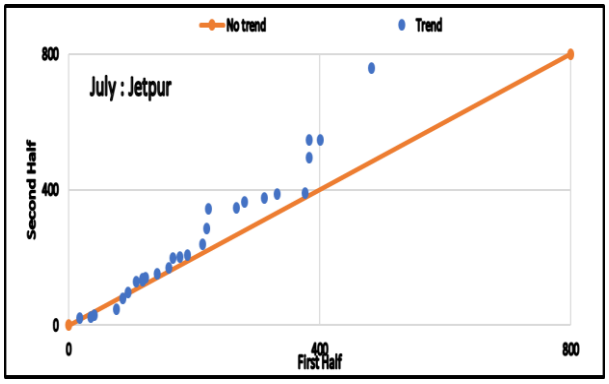

Fig. 4. Innovative Trend Method plot of annual rainfall at station Jetpur

From the Innovative trend plot for annual rainfall at station Jetpur, it is observed that the plot points lies in the upper triangular portion. It indicates increasing magnitude of annual rainfall in the later sub-series (1991-2016) of the total data span (1962-2016).

Thus, it is analyzed that the monthly rainfall for the month of July rainfall at station Jetpur shows positive (increasing) trend from LR method and ITA method both.

The results obtained at all other stations for the monthly rainfall in monsoon months (June to September) for the trend detection are summarized as shown in Table 3.

Table- III: Trend Detection of annual rainfall using LR and ITM method

Sr. No.	Name	Trend positive (Increasing)/Negative (Reducing)							
		LR method				*ITA method*			
		J	*Ju*	*A*	*S*	*J*	*Ju*	*A*	*S*
1	Venu 2	I	I	I	I	I	I	I	I
2	Phoaphal	D	I	I	I	D	I	I	I
3	Kamadhiya	D	D	I	I	D	I	I	I
4	Jepuer	D	I	I	I	D	I	I	I
5	Gondal	I	I	I	I	I	I	I	I
6	Jasadan	I	I	I	I	I	I	I	I
7	Jamjodhpur	D	I	I	I	D	I	D	I
8	Bhadar-1	N	I	I	I	D	I	I	I
9	Uben	I	I	I	I	I	I	I	I
10	Visavadar	D	I	I	I	D	I	I	I
11	Dhoraji	I	I	I	I	I	I	I	I
12	Jasdan	I	I	I	I	I	I	I	I
13	Gondal	I	I	I	I	I	I	I	I
14	Jamkandorna	I	I	I	I	I	I	I	I
15	Ranavav	I	I	I	I	I	I	I	I

J : June; Ju: July; A: August S: September

I: Increasing (Positive) Trend;

D: Decreasing (Negative) Trend

N: No Trend

It is observed from Table III for the trend analysis of monthly rainfall that the results of the trend obtained for monthly rainfall from Linear Regression and Innovative Trend Method are found to be consistent at most of the stations. The trend of

monthly rainfall shows decreasing (Negative) trend in the month of June at 5 stations out of 11 stations. The monthly rainfall shows increasing trend at all stations in the month of July and September.

V. CONCLUSIONS

Bhadar river basin is one of the largest river basin in the Saurashtra region of the state of Gujarat. In this study, the impact of the climate changes have been observed on the rainfall. The trend of the annual rainfall and monthly rainfall is assessed in this study at various raingauge stations in a Bhadar River basin. The trends are analyzed using Linear Regression method and Innovative Trend Method. It is found from the results of the Linear Regression method that the annual rainfall shows positive (increasing trend) trend at all the stations in a Bhadar River basin except one station. While, Innovative Trend method shows positive (increasing trend) at all stations in Bhadar river basin. Thus, except one station, the results of the linear regression method and Innovative trend method shows consistency.

Monthly rainfall for monsoon months (June to September) is also analyzed for the trend assessment. The rainfall in the month of June shows negative (reducing) trend of rainfall at 5 stations, no trend at one station, and increasing trend at 9 stations from Linear Regression method; while it shows negative (reducing trend) at 6 stations and positive (increasing) trend at 9 stations from ITM method. Thus, for the month of June, the results of the trend analysis shows consistent results from LR method and ITA method.

Further, it is analyzed for the month of July, August and September also, the results of the trend analysis from LR method and ITM method are consistent.

As a whole, in the Bhadar River basin, the annual rainfall and monthly rainfall in the month of July, August and September shows increasing trend. While, the monthly rainfall in the month of June shows negative (reducing) trend at some stations.

The annual rainfall in a Bhadar river basin shows increasing at all station except one station.

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