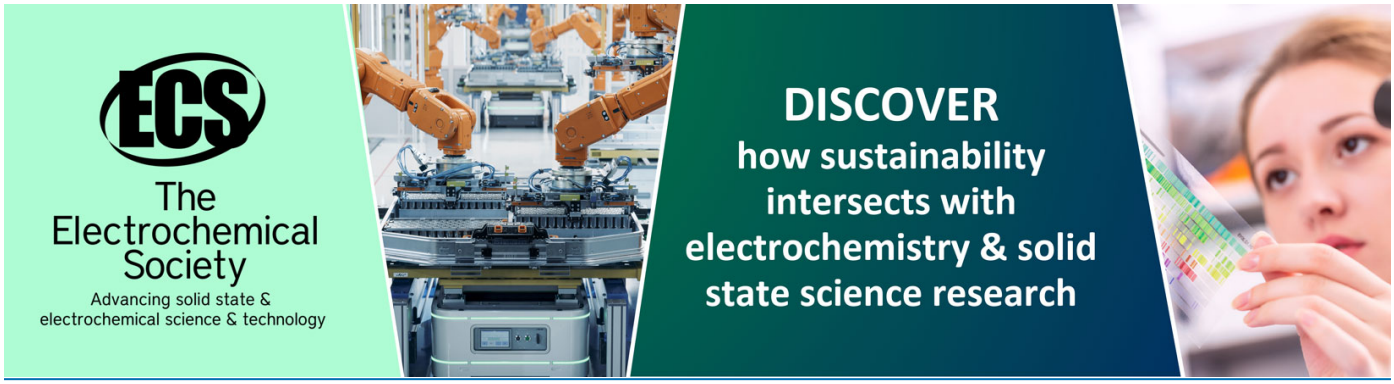
Assessing Impact of Climate Change on Rainfall Patterns of Vadodara District, Gujarat, India



Assessing Impact of Climate Change on Rainfall Patterns of Vadodara District, Gujarat, India

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Abstract. Due to climate change, variable rainfall pattern and rapid urbanization during last two decades, Vadodara district is frequently facing problems related to flooding.In present research paper frequency Analysis is carried from the available hydrometeorologicalhistorical rainfall data series of past four decades for Vadodara District, Gujarat. Rainbow software is used to carry out the analysis. Homogeneity of data is checked and Goodness-of-fit is tested. A logarithm transformation is selected to plot magnitude of event and corresponding probabilities of exceedance. The mixed Global probability distribution is used to explore the re-occurrence of rainfall events with certain return period. Analysis revealed that the rainfall events causing extreme flooding conditions in Vadodara District has frequency of re-occurrence as 25 years.

1. Introduction

Climate change is now global issue. Change in Rainfall pattern is one of the effects of climate change [1]. Every year rainfall occurs for three to four months in most of the districts of India. Floods affect vast areas of the country, sometimes transcending the state boundaries. Proper study as well as prior planning, to manage the circumstance of floods are essential at National level. Design and construction of various rainwater harvesting and hydraulic structures for basic-scale watershed management and flood control requires pattern of rainfall as one of the prime factor. In Vadodara district the rainfall pattern is highly variable. Rainfall mainly occurs in July, August, September and October.Heavy rainfall and flood cause severe damage to livelihood and infrastructure of the city. Erroneous planning and construction near drainage channel is also one of the reasons forflooding in Vadodara district [2]. Both structural and non-structural recommendations are proposed for flood mitigation [3]. Apart from this, various authors have carried out research to analyze rainfall patterns and to address flooding events of Vadodara city using different tools and techniques [4], [5], [6], [7]. Rainbow software is used globally by many researchers to predict the return period of extreme eventsof rainfall in various

basins [8], [9], [10], [11], [12]. In this paper Rainbow software is used to study rainfall pattern and predict the return period of flood causing rainfall events for Vadodara District.

2. Study Area

Vadodara district covers 7794 km^{2}area of Gujarat state. It is famous as Baroda, third largest city of Gujarat stationed 139 km from Gandhinagar capital of Gujarat state. It is located between 21°4''19" and 22°4''37" North latitude and 72°5''05"and 74°16''5" East longitude. Figure 1shows the location map and study area of Vadodara district.

Figure 1. Location and drainage and basin map of Vadodara district
Source: https://www.mapsofindia.com/vadodra/geography/weather.html

Besides, the topography of Vadodara is lying between two major river basins of Narmada and Mahi. Vadodara's weather is normally dry but during mid-June to mid-September it becomes humid. The average rainfall is recorded as 930 mm. Vadodara is located on the banks of river Vishwamitri. Vishwamitri is a small river that is said to dry up in summer. This river originates from Pavagadh Hills in the Panchmahal District of Gujarat and flows mainly through Vadodara City. Heavy rainfall during monsoon causes flooding of the river Vishwamitri, as well as the other rivers of Vadodara. Though the city is now well maintained with good drainage system and various canals, since past two decades the city faced a lot of problems related to flood and water logging.

3. Methodology

In present research work, annual rainfall data of last 40 years (1981-2020) is availed from India-WRIS portal for Vadodara district. Table 1 represents the year wise annual rainfall data for study area.

Year	Annual Rainfall (mm)	Year	Annual Rainfall (mm)
1981	1240.99	2001	915.54
1982	738.24	2002	715.95
1983	1326.65	2003	1085.14
1984	780.11	2004	1137.74
1985	587.6	2005	1222.72
1986	444.95	2006	1625.27
1987	409.34	2007	1295.20
1988	1019.22	2008	859.55
1989	868.12	2009	599.68
1990	1337.11	2010	914.53
1991	617.00	2011	944.92
1992	747.38	2012	901.40
1993	896.59	2013	1439.59
1994	1357.83	2014	864.03
1995	710.39	2015	528.97
1996	1254.84	2016	722.85
1997	1260.44	2017	788.58
1998	1176.80	2018	667.26
1999	507.39	2019	1427.76
2000	514.76	2020	899.00

Table 1 Annual Rainfall for Vadodara District

Rainbow software is used to carry out homogeneity test and frequency analysis for the available historical dataset to obtain an estimate rainfall for selected probabilities or return periods [13]. Cumulative deviation and mean as a central tendency are used to test homogeneity of data. Kolmogorov-Smirnov test at three significant levels (α = 5%, 10% and 20%) is applied in order to study whether dataset follows the proposed certain distribution. Probability of exceedance is derived through Weibull method by ranking the rainfall values in descending order and assigning a serial rank number to each value [14].

4. Data Analysis

The total rainfall received in a given period of time in Vadodara district is found highly variable from one year to another (Figure2).

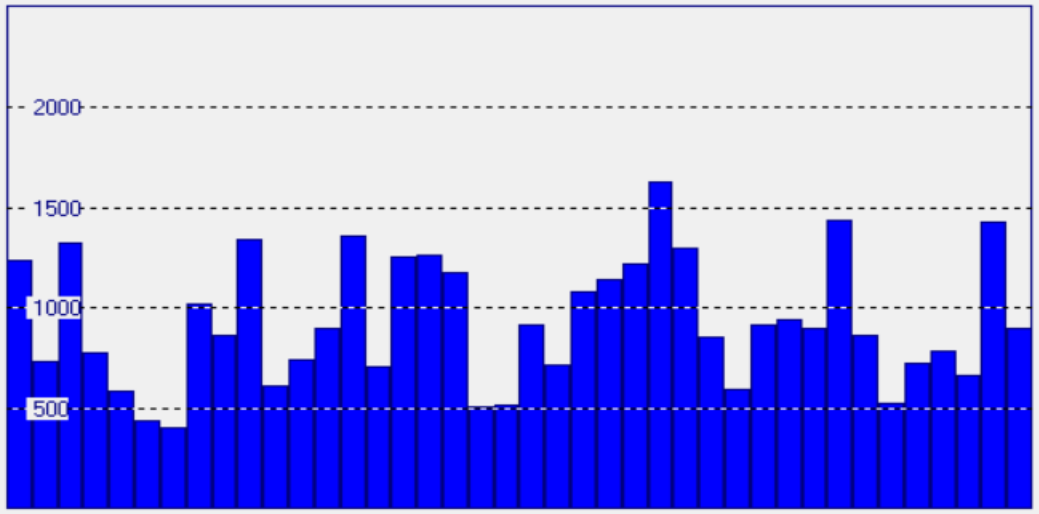

Figure2. Total annual rainfall recorded in Vadodara District for the period of (1980-2020)

Such long series of data can be only useful to predict the specific probability or return period of event if are essentially checked for homogeneity of data. In RAINBOW the cumulative deviation is obtained for the same. The plot of rescaled cumulative deviation from the mean of the total annual rainfall is shown in Figure3.

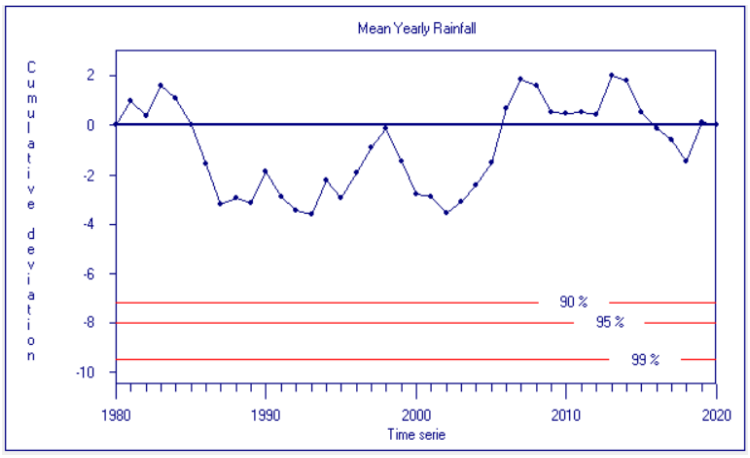

Figure3. Rescaled cumulative deviations from mean (1980-2020)

In RAINBOW software, normal distribution is selected. Frequency analysis of available data is carried out without excluding 'outlier'.A logarithm transformation is selected to reduce the skewness of normal distribution.Figure4 represents the histogram and relative frequency histogram of the observed data which is superimposed with the selected Probability Density Function (PDF). The histogram confirms minimum five observations belonging to each class.

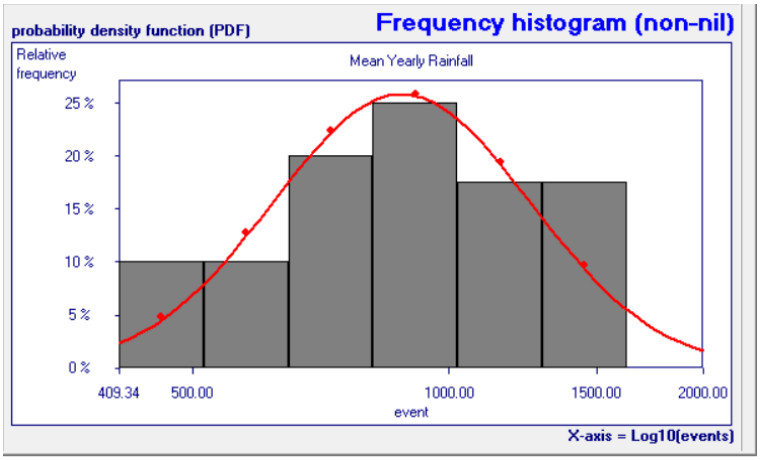

Figure4. Frequency Histogram of Rainfall Data

The magnitude of event and corresponding probabilities of exceedance are derived using Weibull method and plotted as shown in Figure5.

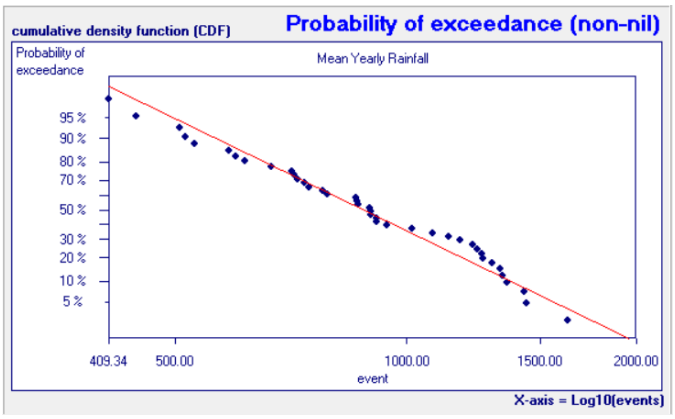

Figure5.Probability of exceedance for Rainfall data (1980-2020)

5. Result and Discussion

Mean annual rainfall through last 40 years of data is observed to be 934 mm with highest rainfall of 1625 mm (during year 2006) and lowest rainfall of 409 mm (during 1987). The reference period of 1980-2020 has revealed two statistically significant periods with different mean: 1980-1995 with a mean annual rainfall of 871 mm and 1996-2020 with a mean annual rainfall of 971 mm. The rise in mean annual rainfall during these two identical periods is represented in Figure6

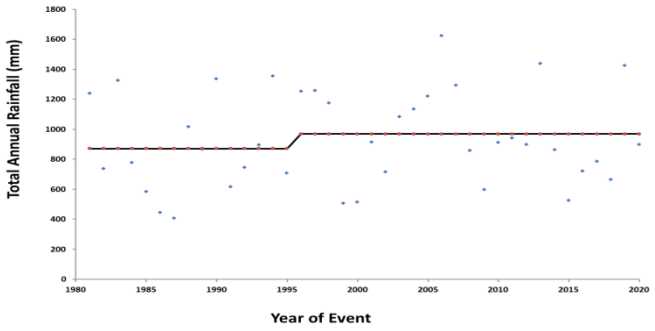

Figure6. Two Distinct Periods with the annual rainfall data

The maximum of cumulative deviation and range (i.e. difference between maximum and minimum values of cumulative deviations) are used to test homogeneity of data.Data is found homogeneous and probability of rejecting homogeneity of data at various probability levels is observed NIL. Goodness-of-fit (R^2) is tested through Kolmogorov-Smirnov test at three significant levels (α = 5%, 10% and 20%) in order to check closeness of linear relationship. R-square value is observed 0.98 with which the proposed distribution can be accepted. Through Histogram the frequency of extreme value of rainfall occurrences is easily observed. PDF has its maximum frequencies at the moderate to high annual rainfall amounts. Vadodara District rarely receives very intensive rainfall occurrences but once they happen the amount of rainfall is very high which can be one the major impacts of climate change. The mixed global probability distribution discussed by Haanis used to explore the re-occurrence of rainfall events with certain return period [15].Table 2 represents various rainfall events and their corresponding return period of re-occurrence.

Rainfall Event (in mm)	Return Periods (in Years)
881	02
1181	05
1377	10
1487	15
1564	20
1622	25
1803	50
1983	100

Table 2 Rainfall Events and their corresponding Return Periods

Recently severe flooding occurred in Vadodara District during 2013 and 2019 with annual rainfall of 1439 and 1427 mm respectively. Rainfall events causing such flooding have been predicted more frequent to occur. The analysis revealed that more than 1622 mm rainfall which can cause extreme flooding conditions in Vadodara City has frequency of 25 years to re-occur.

6. Conclusion

- Rainfall pattern of Vadodara District has been observed changing since last two decades. Climatic changes can be considered as governing factor for such variations. Change in Climate shows need of action plan and policy for sustainable development.
- Rainbow is found user friendly for statistical analysis of historical data.
- The proposed analysis of extreme rainfall events can be used for basin-scale watershed management and for flood risk management. Such frequency analysis of extreme events of rainfall can be used for planning and construction of new rainwater harvesting and hydraulic structures in Vadodara district.
- Estimation of yearly dependable rainfall from yearly normal distributed rainfall data series for efficient working of irrigation scheme can be future scope of study.

7. Acknowledgement

Authors are thankful to INDIA-WRIS for providing ‘Single Window’ source of updated historical database for Vadodara District.

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