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Rainfall Variability Trend in Porbandar, Gujarat

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Abstract:
Rainfall is a principal element of the hydrological cycle and its variability is important from both scientific as well as socioeconomic points of view. This study presents an analysis based on the rainfall variation over 31 years from 1991 to 2021 in Porbandar, Gujarat located in the western region of India. The data were analyzed using fundaments statistical parameters and trends in rainfall were investigated using Mann-Kendall Test and Sen's method. In Porbandar, the average monsoon rainfall from 1991-2020 for the monsoon months of May to October is about 539.11 mm. Mann-Kendall value Z and Sen's estimator β show the non-significant but decadal-increasing trend in rainfall. The negative value of Z statistic and Sen's estimator β for the month of August, September, and October shows a non-significant downward trend while the positive for July month shows a non-significant upward trend. Overall, there is a steadily increasing trend of rainfall in Porbandar. These observed changes in rainfall, although most time series are not convincing as they show predominantly no significance, along with the well-reported climatic warming in monsoon and post-monsoon seasons may have implications for human health and water resources management over bio-diversity-rich Porbandar district.

Keywords: Rainfall, Porbandar, Mann-Kendall Test, Sen's Method

INTRODUCTION

Hydrological processes are usually regarded as stationary; however, there is growing evidence of trends, which may be related to anthropogenic influences and natural features of the climate system [1]. Serious concerns are drawn on the catastrophic nature of floods, droughts, and storms caused due to the significant variations in the regional climate including the rainfall pattern taking place on a regional level. Trends in precipitation have been observed for the last century in many parts of the globe. Over this period, precipitation increased significantly in eastern parts of North and South America, northern Europe, and northern and central Asia whereas precipitation declined in the Sahel, the Mediterranean, southern Africa, and parts of southern Asia [1].

Southwest monsoon rainfall over India exhibits variability in all time scales from diurnal to epochal. The yearly variability of monsoon rainfall has been studied by many researchers [2, 3, 4, 5]. Sinha Ray and Srivastava [6] have reported a decreasing trend in rainfall over most parts of the country except over northwest India and a few stations in northern India. Joshi and Rajeevan [7] have observed an increasing trend in monsoon rainfall over the west coast and northwest India. A preliminary analysis by Ray et al. [8] using 40 years of data for Gujarat found that mean seasonal rainfall has increased over Saurashtra and south Gujarat region (along the west coast) and has remained more or less the same over the north Gujarat region and adjoining Kutch.

Climate change, in particular, the rainfall variability has become a major abiotic factor affecting the prospect of agriculture, livelihood security, flood management, availability of fresh water, and melting of glaciers. Information on the temporal and spatial distribution of rainfall is important for a variety of applications in hydrology and water resources management [9].

METHODOLOGY

Study Site

Porbandar is situated in the western part of the Kathiawar Peninsula on the Arabian Sea coast. The geographical location of Porbandar is 69° 36' 21.4740'' E Longitude and 21° 38' 26.0700'' N Latitude. This district was carved out of Junagadh District and is surrounded by Jamnagar and Devbhoomi Dwarka districts to the north, Junagadh and Rajkot districts to the east, and the Arabian Sea to the west and south [10]. The general climate of the district is sub-tropical and is characterized by three well-defined seasons, i.e., summer - from April to June, monsoon - from July to September, and winter - from October to March. Mean maximum daily temperatures range from 29 to 34°C and mean minimum daily temperatures from 14 to 27 °C. The average precipitation days (≥ 1.0 mm) is 1.82 [11]. The average relative humidity (%) is 62.68 [11]. The mean monthly sunshine hours are 10.61 [11]. The location map as well as the study area is shown in Fig. 1.

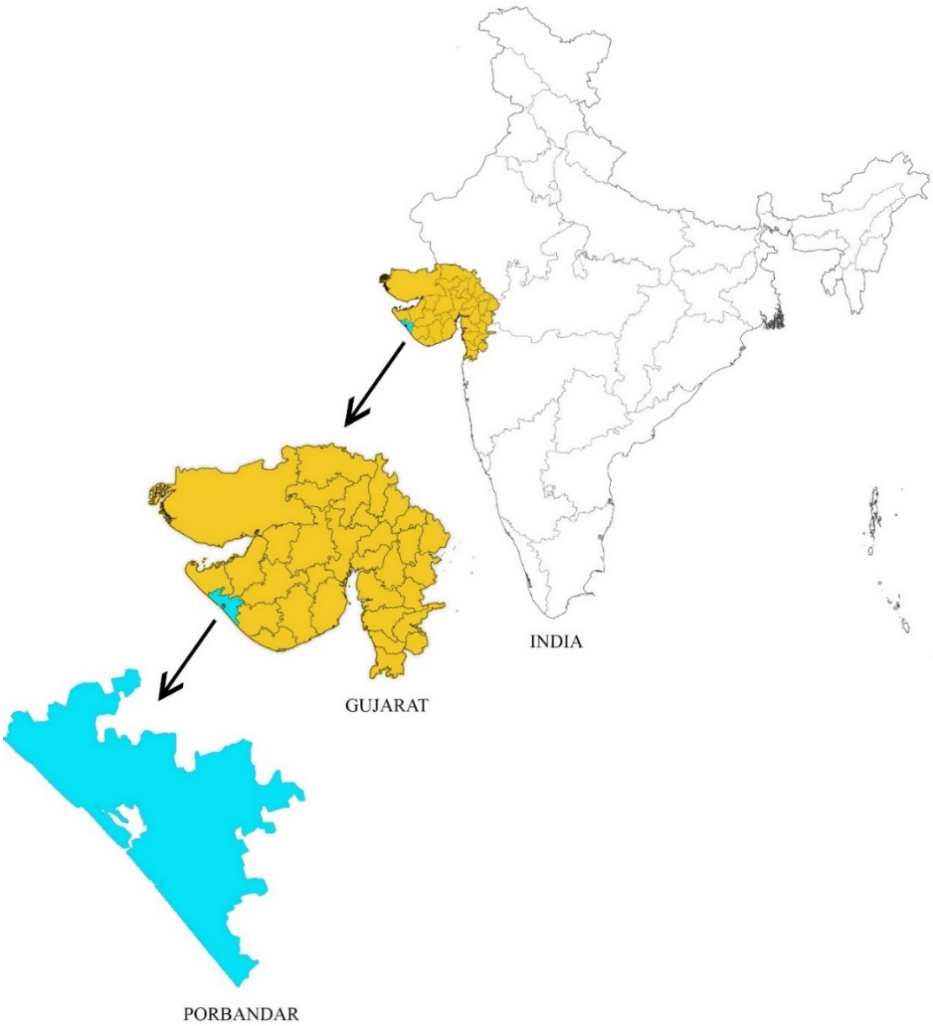

Fig. 1: Location Map of Study Area

Data Collection

The monthly rainfall data is downloaded from Indian Meteorological Department's Climate Data Online portal [12] using Chat GPT an AI language model developed by Open AI for the period 1991-2021. India Metrological Department (IMD) has defined four climate seasons viz. winter (January to February), pre-monsoon (March to May), monsoon (June to September), and post-monsoon (October to December). The rainfall data for May, June, July, August, September, October, and monsoon season data were prepared using the monthly rainfall data.

Statistical Analysis

At first, the data were divided into decadal basis viz. 1991-2000, 2001-2011, and mean rainfall per month for the whole monsoon season were obtained. The data were statistically analyzed using basic statistical parameters like mean, standard deviation, skewness, and kurtosis. In general, trend analysis can be done by both parametric and non-parametric tests but in this present work, the non-parametric tests were done as it does not require data to be normally distributed and free from outliers. In the present work, the Mann-Kendall test and Sen's slope method were used to detect the direction and magnitude of a trend.

Mann-Kendall Test:

Mann–Kendall test, this non-parametric test, which is usually known as Kendall's statistic, has been widely used to test for randomness against trends in hydrology and climatology [13].
The Mann-Kendall statistics S is given as

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

Where x_i and x_j are time series ranked from i=1,2 ..., n-1 and j=i+1...,n respectively.

$$Sgn(x) = \begin{cases} 1, & if\ x > 0 \\ 0, & if\ x = 0 \\ -1, & if\ x < 0 \end{cases}$$

A positive sign of statistic S indicates an upward trend while the negative sign indicates a downward trend of the data. For the sample size n ≥8, variance of the Mann-Kendall statistics is given by

$$\mathrm{Var(S)} = \frac{[\mathrm{n(n-1)(2n+5)} - \sum_t \mathrm{t(t-1)(2t+5)}]}{18}$$

Where t is the extent of any given tie.

The standard normal variable **Z** is computed by

$$\boldsymbol{Z} = \begin{cases} \dfrac{S-1}{\sqrt{Var(S)}} & if\ S > 0 \\ 0\ if\ S =\ 0 & \\ \dfrac{S-1}{\sqrt{Var(S)}} & if\ S < 0 \end{cases}$$

The **Z** follows a standard normal distribution and **Z**>o signifies an upward trend whereas **Z**<o signifies a downward trend.

Sen's Method:
Sen's estimator. If a linear trend is present in a time series, then the true slope (change per unit time) can be estimated by using a simple non-parametric procedure developed by Sen in 1968 [14].

The slope of the trend line in the sample of N pairs of data can be estimated by

$$Q = \frac{x_j - x_i}{j - i}$$

Where x_j and x_i are the data values at times j and i (j>i) respectively.

The median of these N values of Q is Sen's estimator of slope which is calculated as

$$\boldsymbol{\beta} = \begin{cases} Q\left(\frac{N+1}{2}\right) & \text{if N is Odd} \\ \frac{Q\left(\frac{N}{2}\right) + Q\left(\frac{N+2}{2}\right)}{2} & \text{if N is Even} \end{cases}$$

In the end, **β** is computed by a two-sided test at 100 (1-α) % confidence interval and then a true slope can be obtained by the non-parametric test. A positive value of **β** indicates an upward or increasing trend and a negative value of **β** gives a downward or decreasing trend in the time series.

RESULT AND DISCUSSION

Preliminary Analysis

According to data obtained, in Porbandar rainy days belong to six months May to October. The average rainfall in Porbandar during the period of 1991-2021 is 539.11 mm. The average rainfall per year is shown in Fig. 2. The average rainfall par the last three decades is shown in Table 1. The highest average rainfall is observed during the last decade (2011-2021). The decadal distribution of monthly rainfall is shown in Fig. 3.

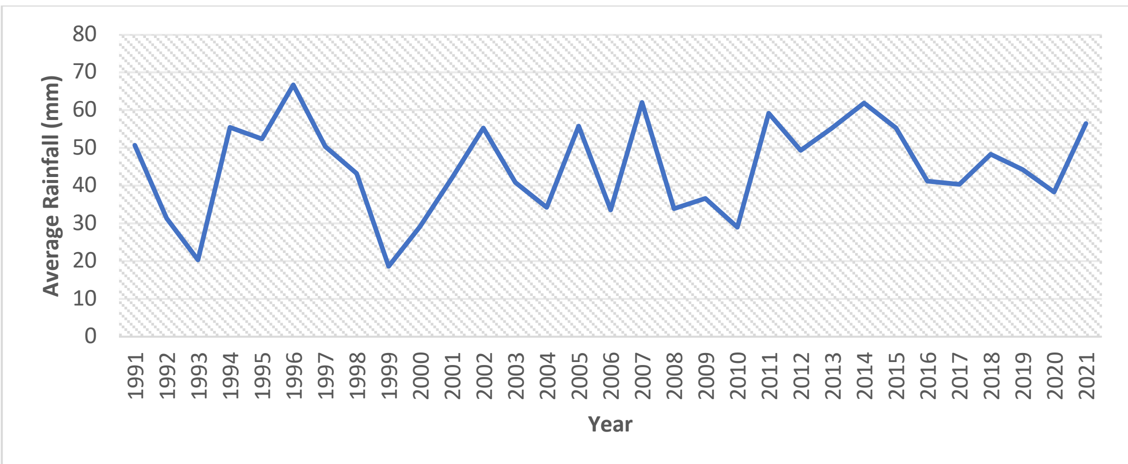

Fig. 2: Average rainfall per year for the period of 1991-2021 in Porbandar

Table 1: Average decadal rainfall in Porbandar

Decade	Average rainfall (mm)
1991-2000	502.32
2001-2010	508.51
2011-2021	600.38

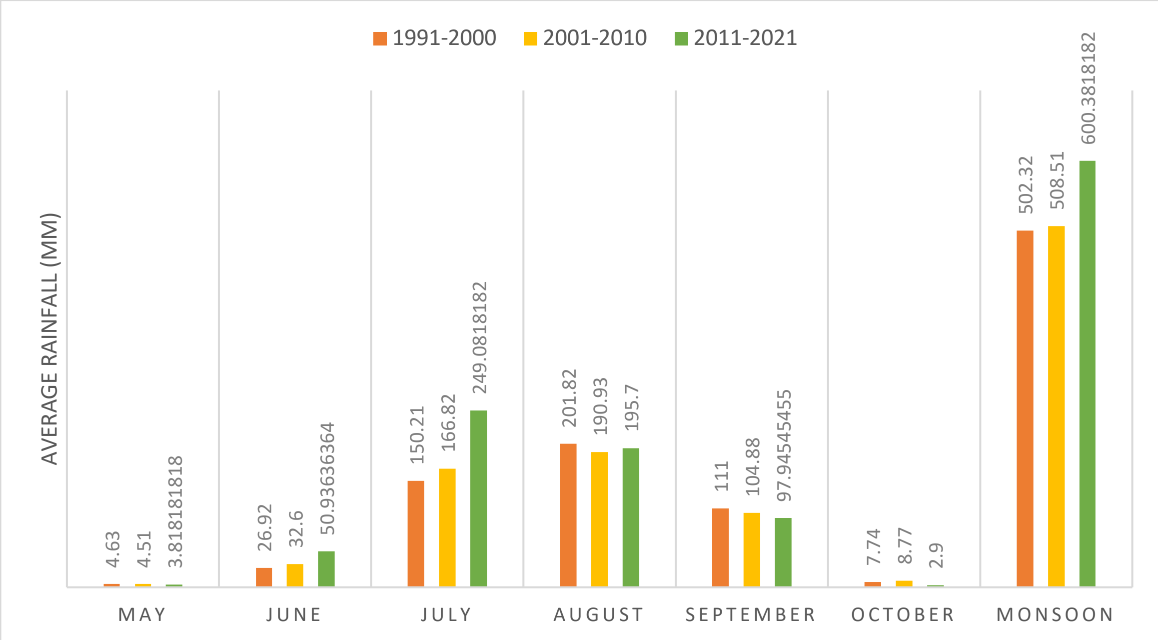

Fig. 3: Decadal distribution of monthly rainfall of Porbandar (1991-2021)

The mean rainfall of the monsoon season from 1991-2022 is 539.112 mm and SD is 149.060. The skewness, which is a measure of the asymmetry in frequency **distribution** around the mean, is -0.313 indicating that the monsoon rainfall is not much asymmetric and lies to the right over the period 1991-2022. Kurtosis, which describes the peakedness of a symmetrical frequency distribution, is -0.618 for the monsoon season. (Table 2).

Table 2: Statistical parameters of rainfall from 1991-2022 of Porbandar

Time Series 1991-2021	Mean (mm)	SD (mm)	Skewness	Kurtosis
May	4.303	6.252	2.061	4.548
June	37.274	32.688	1.100	1.005
July	190.651	83.446	0.026	-1.095
August	196.135	65.947	0.071	-0.822
September	104.393	36.938	0.873	1.346
October	6.354	6.984	1.367	1.472
Monsoon	539.112	149.060	-0.313	-0.618

Trends in Rainfall

Mann-Kendall Test showed no significant trend in monsoon season rainfall (Table 3). The negative value of **Z** statistics for the month of August, September, and October shows a downward trend. The **Z** value for the month of July is 2.8554 which shows a statistically increasing trend.

Sen's method showed an increasing trend in monsoon season rainfall (Table 3). The negative value of **β** statistics for the month of August, September, and October shows a downward trend. The **β** value for the month of July is 4.80 which shows a statistically increasing trend.

Table 3: Mann-Kendall value Z and Sen's estimator value β for the period 1991-2022

Time Series 1991-2021	Mann-Kendall value (**Z**)	Sen's estimator (**β**)
May	0.13852	0
June	0.9518	0.56
July	2.8554	4.80
August	-1.2577	-2.15
September	-1.0878	-0.75
October	-1.6174	-0.18
Monsoon	0.61187	2.15

CONCLUSION

Precipitation, being one of the most important variables has an influence on ecosystems and agriculture and their response to climate change. The statistical analysis of the rainfall data of Porbandar from 1991-2021 shows that there is an increase in average rainfall in the last decade (2011-2021). The month of July shows an increasing trend while the month of August, September, and October shows decreasing trend. Overall, there is non-significant but a steadily increasing trend of rainfall in Porbandar. It is hoped that this analysis will provide input data for a management system and to enable the development of optimal water allocation policies and management strategies for water and agriculture manager to bridge the gap between water needs and obtainable water supply.

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