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INTERPRETING THE EFFECTS OF CLIMATE CHANGE ON PRECIPITATION IN NAVSARI, GUJARAT: TRENDS, VARIABILITY AND IMPLICATIONS

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ABSTRACT

Studying the variability of rainfall holds significant importance in the dominion of agriculture. To facilitate the optimal planting of crops in the face of climate fluctuations, agro-meteorologists predominantly depend on rainfall distributions. These distributions serve as a crucial tool for understanding the rainfall patterns within a specific area. This study undertaken a thorough examination of precipitation trends in the Navsari district of Gujarat, utilizing the data from the years 1984 to 2023 under the influence of climate change. The study utilized descriptive statistics to assess the characteristics of rainfall, while the Mann-Kendall test is utilized to determine the trend in rainfall patterns. Additionally, the Standard Precipitation Index (SPI) was calculated to quantify the degree of wetness in the region. It was observed that over the four period, Navsari viewed an annual mean rainfall of 1652.68 mm, accompanied by a standard deviation of 468.11 mm and a Coefficient of Variation (CV) of 28.32 per cent, indicating notable inconsistency in annual rainfall. Out of forty years, in thirteen years observed that onset of monsoon was delayed ranging from 1 to 12 days whereas in nineteen years observed early withdrawal of monsoon was ranging from 2 to more than 15 days. The normal monsoon duration was 111 days, it was observed that during the study period it became more in eighteen years but became less in twenty-two years, experiencing the highest number of monsoon days in the year 1996 and the least in 1986. Additionally, it was observed that noticeable increased in very wet months in the last period. Season-wise SPI analysis identified extreme wet conditions in post-monsoon (1996, 1999) winter (1994, 2014) and pre-monsoon (2021) seasons.

Keywords: Climate change, Mann-Kendall test, Rainfall Variability, Standard Precipitation Index, Trend.

Introduction

Rainfall variability is a key factor for predicting the processes in agriculture, hydrology, and climatology. The distribution and amount of rainfall are significantly impacted by climate change (Singh *et al.,* 2021). Rainfall remains one of the most influential meteorological parameters in many aspects of our daily lives. Any variation in rainfall has an impact on the management of water resources, accessibility to fresh water, food production, and nutritional security, both directly and indirectly (Hu *et al.,* 2017).

Most of the farmers are smallholders who depend more on rainfed agriculture rather than irrigated agriculture. Many people utilize rainfall distributions to understand the area's rainfall pattern for effective crop planning in a changing climate. In India, there have been several research done that examined trends in annual and seasonal rainfall (Krishnakumar *et al.,*

2009; Mondal *et al.,* 2015; Kundu *et al.,* 2015). Many researchers also study the rainfall patterns in Gujarat state (Kumar *et al.,* 2017; Priyan, 2015; Patel *et al.,* 2021).

In the non-parametric, the Mann-Kendall test (Mann, 1945 and Kendall, 1975) is widely used in the study of hydrometeorology to detect the significance trend in time series data (Shukla *et al.* 2014; Sandhu and Kaur, 2023) and Standard Precipitation Index (SPI) approach has been used to identify the rainfall patten monthly and seasonally for Navsari area (Das *et al.,* 2022). This study has undertaken an assessment of both seasonal, periodical and annual rainfall trends and variations to gain a more comprehensive understanding of the recent changes in rainfall patterns in the Navsari area.

Materials and Methods

Study Area

The study area of Navsari is located between 20°32' to 21°05' North Latitude and 72°42' to 73°30' East Longitude (Figure 1) and IMD station which is located at Navsari Agricultural University.

Meteorological data

Monthly rainfall data collected from the Agro-Meteorological Cell, Department of Agricultural Engineering, N. M. College of Agriculture, Navsari Agricultural University, Navsari for the years of 1984 to 2023 for this study.

Research Methodology

For this study, data divide into four period *viz.,* P1, P2, P3 and P4 consider as year of 1984 to 1993, 1994 to 2003, 2004 to 2013 and 2014 to 2023, respectively as well as the whole data. January and February, March to May, June to September and October to December consider as winter, pre-monsoon, monsoon and post-monsoon season, respectively.

Computational Method

The initial assessment of rainfall contains mean, Standard Deviation (SD) and Coefficient of Variance (CV) for monthly, seasonal and period wise to analyze and understand the behavior of rainfall in Navsari station.

Mann-Kendall non-parametric test is applied for detection of rainfall trend in Navsari station. Mann-Kendall test statistics calculated as follows; (Varshney and Satpathy, 2017)

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

$$\mathrm{sgn}(x_j - x_i) = \begin{cases} +1, > (x_j - x_i) \\ 0, = (x_j - x_i) \\ -1, < (x_j - x_i) \end{cases}$$

Where x_i and x_j represent the data at time i and j. Positive S value indicate the positive trend and negative S value indicate negative trend. Statistically evaluate the significance of the trend, it is necessary to determine the probability associated with S and the sample size n. variance is as follows;

$$Var\,(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_j(t_j-1)(2t_j+5)}{18}$$

Where n is data point, m is tied groups and t_j is data in j^{th} tied group. Z transformation is applied as follows;

$$Z = \begin{cases} \frac{S \pm 1}{\sqrt{Var(S)}} & \text{if } S \neq 0 \\ 0 & \text{if } S = 0 \end{cases}$$

Degree of wetness is calculated by Standard Precipitation Index (SPI) for monthly total rainfall data. SPI is calculated as follows; (das *et al.,* 2022). The SPI is used to predict whether conditions will be wet or dry based on precipitation factors. This state of wetness or dryness can be observed by the SPI over different time frames, spanning sub-seasonal to inter-annual scales.

$$SPI = \frac{(r_{ij} - r_{im})}{\sigma}$$

Where r_{ij} indicate rainfall at i^{th} station for j^{th} observation, rim indicate long term mean rainfall and σ indicate standard deviation. According to McKee *et al.* (1993), SPI classified into seven classes (Table 1).

Results and Discussion

Descriptive Statistics of Rainfall in Navsari

Descriptive statistics of rainfall in Navsari station were calculated monthly and seasonally for 1984 to 2023 year and presented in Table 2. For the period of forty years, mean of annual rainfall in Navsari station is 1652.68 mm with SD of 468.11 mm and CV of 28.32 per cent indicating that the annual rainfall was inconsistent in this area, average of the monsoon rainfall season is 1600.20 mm with SD of 477.19 mm and CV of 29.82 per cent and out of all month, July month have highest rainfall (650.22 mm) which lowest CV of 48.56 per cent followed by August month (358.2 mm) but it contains inconsistent in rainfall and least rainfall obtain in April month (0.29 mm).

In period wise analysis (Table 3), highest average rainfall occurs in P3 period (1952.36 mm) followed by P4 period (1768.7 mm) with CV of 19.96 and 23.10

per cent, respectively indicating consistent in rainfall in P3 period as compare to another period. In monthly period wise analysis, mostly July month indicate lowest CV (55.55, 39.78 and 44.43 in P2, P3 and P4, respectively) except P1 period so that it indicates now a days CV is continuously decreasing in July month and highest rainfall occurs in July month (591.31, 591.13, 701.59 and 716.87 in P1, P2, P3 and P4, respectively) and it indicate highest in P3 period.

Trend Analysis of rainfall in Navsari

Mann-Kendall test applied for trend of rainfall in Navsari area and concluded in Table 4. For the period of forty years, among all season, Monsoon season having significantly increasing trend (z-value is 2.31) whereas Winter, Pre-monsoon and post-monsoon season have no trend. From this monsoon season, September month having significantly increasing trend (z-value is 2.97) whereas remaining month have no trend. The graphical representation of month wise and season wise z-statistics value given in the Figure 2 and Figure 3, respectively.

P4 period having significant increasing trend (z-value is 2.14) in Monsoon season, whereas remaining season have no trend in other period (P1, P2 and P3). In P2 period, January month having decreasing trend (z-value is -2.54).

Variability in onset, withdrawal and duration of monsoon in Navsari

The monsoon season start in Navsari on the 15th June and withdrawal in 3rd October. The variability in onset of monsoon, withdrawal of monsoon and duration of monsoon in Navsari during 1984 to 2023 (40 years) are presented in Table 5 and Figure 4. The onset of monsoon in Navsari was delayed for thirteen years ranging from 1 to 12 days whereas earlier in twenty-five years ranging from 1 to 14 days and year of 1997 and 2011 shows onset of monsoon on 15 June. The normal withdrawal of monsoon in Navsari should occur up to 3rd October, delay of withdrawal occurs in twenty years whereas ranging from 1 to more than 15 days.

The normal duration of monsoon in Navsari is 111 days (15th June to 3rd October). Out of this, eighteen years occurs more duration compare to normal and remaining twenty-one years observed less duration of monsoon as compare to normal and 1989' year shows 111 days of duration of monsoon. Highest monsoon days occurs in the year of 1996 and least monsoon days in 1986. Kuthe *et al.* (2015) concluded that during the monsoon season, rainfall is the main variable out of all-weather variables and change in climate in Navsari and this is highly affecting the agriculture sector. The study also showed that onset of monsoon affects the initial growth and germination. So that delayed monsoon which is highly affecting on crop physiology and yield due to changes in weather parameters.

Standard Precipitation Index (SPI)

The monthly and season wise SPI of Navsari is presented in Table 6 and Table 7 respectively. According to SPI calculation month wise, maximum two month occurs extremely wet condition among the year *viz.* 1994 (January and June), 2002 (March and April), 2014 (January and November), 2018 (July and December), 2020 (August and December), 2021 (May and December) and 2023 (April and November). So that in last decade, extremely wet months are more occupied (Twelve month). July month having severely dry condition in year of 1990 and 2002.

In season wise SPI index, extremely wet condition in Post monsoon season occurs in year of 1996 and 1999, extremely wet condition in winter season occurs in year of 1994 and 2014 whereas pre monsoon season having extremely wet condition in year of 2021 pre monsoon season. In the year of 1999, monsoon season having severely dry condition. The situation of water scarcity in many areas of Navsari, makes it necessary to implement affordable technology that could collect rainwater in order to meet drinking water needs (Dwivedi and Shrivastava, 2021).

Conclusion

This study revealed that, Rainfall distribution is inconsistent over the Navsari area and highest rainfall occurs in July month. For the rainfall trend, the monsoon season has a significantly increasing trend and out of this, September month has significantly increased trend in Navsari area during the period of 1984 to 2023 years. The study reveals a significant annual rainfall mean of 1652.68 mm with remarkable variability. Monsoon onset delays, withdrawal variations, and deviations from the normal 111-day monsoon duration were observed. Extremely wet condition is more observed in last period as compare to another. Season-wise SPI analysis identified extreme wet conditions in post-monsoon, winter, and pre-monsoon seasons. These findings contribute vital insights for informed agricultural practices and climate adaptation in the Navsari region. By understanding rainfall fluctuations, farmers can implement adaptive strategies, such as choosing drought-resistant crops or optimizing irrigation practices, to mitigate the risks associated with unpredictable weather patterns.

Table 1 : SPI classification rule and values

Precipitation rule	Range of SPI values	Colors indicators
Extremely wet	≥ +2.0	
Very wet	+1.5 < SPI ≤ +2.0	
Moderately wet	+1.0 < SPI ≤ +1.5	
Normal	-1.0 < SPI ≤ 1.0	
Moderately dry	-1.5 < SPI ≤ -1.0	
Severely dry	-2.0 < SPI ≤ -1.5	
Extremely dry	≤ -2.0	

Table 2 : Monthly, Seasonal and Annual rainfall in Navsari for the period of 1984 to 2023

Month/Season	Mean	SD	CV (%)
Jan	1.51	4.95	327.6
Feb	0.53	2.05	382.7
Mar	0.57	1.85	321.6
Apr	0.29	0.97	329.1
May	6.12	23.61	385.6
Jun	304.91	248.80	81.6
Jul	650.22	315.72	48.56
Aug	358.2	241.14	67.32
Sep	286.86	205.58	71.67
Oct	30.94	44.52	143.9
Nov	7.80	15.57	199.6
Dec	4.68	13.28	284
Winter	2.05	5.20	254.00
Pre-Monsoon	7	23.50	335.78
Monsoon	1600.20	477.19	29.82
Post-Monsoon	43.43	47.35	109.02
Annual	1652.68	468.11	28.32

Table 3 : Monthly, Seasonal and Annual rainfall in Navsari for the period of P1, P2, P3 and P4

Month/ Season	P1			P2			P3			P4		
	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)
Jan	0	0	-	4.45	8.50	191.11	0.2	0.63	316.22	1.4	4.42	316.22
Feb	0.19	0.60	316.23	1.56	3.83	246.07	0.4	1.26	316.22	0	0	-
Mar	0.63	1.47	233.77	0.45	1.42	316.22	0	0	-	1.23	3.14	255.60
Apr	0	0	-	0.32	0.70	218.89	0.32	1.01	316.22	0.55	1.57	285.71
May	4.64	14.29	307.99	3.2	5.13	160.46	1.86	2.93	157.87	14.8	45.41	306.84
Jun	300.81	173.68	57.74	360.41	285.96	79.34	343	355.92	103.76	215.45	125.23	58.12
Jul	591.31	359.35	60.77	591.13	328.42	55.55	701.59	279.11	39.78	716.87	318.52	44.43
Aug	278.71	149.28	53.56	322.18	185.97	57.72	464.71	215.99	46.47	367.2	356.80	97.16
Sep	209.99	184.53	87.87	163.83	129.22	78.87	384.22	182.91	47.60	389.4	230.94	59.30
Oct	26.78	45.08	168.33	43.27	62.77	145.08	21.84	26.55	121.56	31.9	40.39	126.61
Nov	3.55	7.94	223.77	5.44	11.98	220.35	6.52	12.65	194.16	15.7	24.21	154.24
Dec	0.53	1.68	316.23	3.29	6.07	184.66	0.7	2.21	316.22	14.2	24.10	169.75
Winter	0.19	0.60	316.22	6.01	8.46	140.82	0.6	1.34	224.98	1.4	4.42	316.22
Pre-Monsoon	5.27	14.13	268.28	3.97	5.29	133.46	2.18	2.93	134.58	16.58	44.90	270.81
Monsoon	1380.82	450.70	32.64	1437.55	531.54	36.97	1893.52	385.76	20.37	1688.92	406.27	24.05
Post-Monsoon	30.86	43.83	142.03	52	63.53	122.18	29.06	34.46	118.58	61.8	41.32	66.87
Annual	1417.14	445.10	31.41	1499.53	501.45	33.44	1925.36	384.36	19.96	1768.7	408.65	23.10

Note: P1=1984 to 1993, P2=1994 to 2003, P3=2004 to 2013 and P4=2014 to 2023

Table 4 : Mann-Kendall test statistics of rainfall in Navsari station

Month /Season	P1			P2			P3			P4			(1984-2023)		
	z-value	P value	Trend	z-value	P value	Trend	z-value	P value	Trend	z-value	P value	Trend	z-value	P value	Trend
Jan	0.00	1.00	N	-2.54	0.01	D	-0.34	0.72	N	-1.39	0.16	N	-0.71	0.47	N
Feb	0.34	0.72	N	1.29	0.19	N	0.0	1.0	N	0.0	1.0	N	-0.51	0.60	N
Mar	1.29	0.19	N	1.04	0.29	N	0.0	1.0	N	-0.55	0.57	N	0.58	0.55	N
Apr	0.0	1.0	N	0.51	0.60	N	1.39	0.16	N	0.25	0.79	N	1.38	0.16	N
May	-0.25	0.79	N	0.30	0.76	N	0.71	0.47	N	0.25	0.79	N	0.10	0.91	N
Jun	0.17	0.85	N	1.07	0.28	N	-0.89	0.37	N	1.07	0.28	N	-0.73	0.46	N
Jul	0.00	1.0	N	-0.71	0.47	N	-1.07	0.28	N	0.89	0.37	N	0.89	0.36	N
Aug	-0.35	0.72	N	1.60	0.10	N	0.0	1.0	N	0.0	1.0	N	0.89	0.36	N
Sep	1.07	0.28	N	-0.35	0.72	N	1.96	0.04	I	0.35	0.72	N	2.97	0.002	I
Oct	1.15	0.24	N	-0.63	0.52	N	1.16	0.24	N	0.09	0.92	N	0.90	0.36	N
Nov	0.0	1.0	N	-0.25	0.79	N	0.33	0.73	N	0.30	0.76	N	1.36	0.17	N
Dec	-0.34	0.72	N	0.55	0.57	N	0.0	1.0	N	0.77	0.43	N	1.08	0.27	N
Winter	0.34	0.72	N	-1.48	0.13	N	-0.25	0.79	N	-1.39	0.16	N	-0.92	0.35	N
Pre-Monsoon	0.91	0.35	N	0.96	0.33	N	0.71	0.47	N	0.0	1.0	N	0.76	0.44	N
Monsoon	0.0	1.0	N	0.17	0.85	N	-0.89	0.37	N	2.14	0.03	I	2.31	0.02	I
Post-Monsoon	0.92	0.35	N	-0.89	0.37	N	0.89	0.37	N	0.0	1.0	N	1.55	0.12	N

Notation: N = No Trend, **I**=Increasing Trend and **D** =Decreasing Trend

Table 5 : Variability in onset, withdrawal and duration of monsoon in Navsari

Year	Onset date	Deviation from Normal (Days)	Withdrawal date	Deviation from Normal (Days)	Duration of Monsoon
1984	13-Jun	2	21-Sep	-12	100
1985	1-Jun	14	10-Oct	7	131
1986	17-Jun	-2	5-Sep	-28	80
1987	12-Jun	3	13-Sep	-20	93
1988	16-Jun	-1	1-Oct	-2	107
1989	10-Jun	5	29-Sep	-4	111
1990	1-Jun	14	11-Oct	8	132
1991	7-Jun	8	21-Sep	-12	106
1992	20-Jun	-5	17-Oct	14	119
1993	12-Jun	3	25-Oct	22	135
1994	10-Jun	5	19-Sep	-14	101
1995	17-Jun	-2	19-Oct	16	124
1996	12-Jun	3	28-Oct	25	138
1997	15-Jun	0	5-Oct	2	112
1998	9-Jun	6	18-Oct	15	131
1999	19-Jun	-4	13-Oct	10	116
2000	7-Jun	8	6-Sep	-27	91
2001	13-Jun	2	10-Oct	7	119
2002	17-Jun	-2	18-Sep	-15	93
2003	17-Jun	-2	1-Oct	-2	106
2004	16-Jun	-1	1-Oct	-2	107
2005	23-Jun	-8	24-Sep	-9	93
2006	25-Jun	-10	3-Oct	0	100
2007	21-Jun	-6	28-Sep	-5	99
2008	10-Jun	5	6-Oct	3	118
2009	27-Jun	-12	9-Oct	6	104
2010	8-Jun	7	12-Oct	9	126
2011	15-Jun	0	27-Sep	-6	104
2012	8-Jun	7	7-Oct	4	121
2013	8-Jun	7	10-Oct	7	124

2014	13-Jun	2	14-Sep	-19	93
2015	9-Jun	6	22-Sep	-11	105
2016	22-Jun	-7	7-Oct	4	107
2017	8-Jun	7	14-Oct	11	128
2018	6-Jun	9	23-Sep	-10	109
2019	14-Jun	1	4-Oct	1	112
2020	10-Jun	5	27-Sep	-6	109
2021	5-Jun	10	13-Oct	10	130
2022	12-Jun	3	9-Oct	6	119
2023	14-Jun	1	27-Sep	-6	105
Normal	**15-Jun**		**03-Oct**		**111**

Table 6 : Monthly SPI value of Navsari Area

Year	January	February	March	April	May	June	July	August	September	October	November	December
1984	-0.305	-0.261	-0.311	-0.304	-0.259	0.164	-0.425	-0.258	-0.104	-0.695	-0.501	-0.352
1985	-0.305	-0.261	-0.311	-0.304	-0.213	-0.755	-0.957	0.632	-0.915	2.283	-0.501	-0.352
1986	-0.305	-0.261	-0.311	-0.304	-0.259	0.396	0.369	-0.907	-1.327	-0.695	-0.501	-0.352
1987	-0.305	-0.261	-0.311	-0.304	-0.259	-0.287	-0.604	-0.113	-1.362	-0.695	0.276	0.047
1988	-0.305	-0.261	-0.311	-0.304	-0.259	-0.260	2.539	-0.700	0.418	-0.533	-0.501	-0.352
1989	-0.305	-0.261	0.658	-0.304	-0.259	-0.282	-0.292	-0.577	-0.844	-0.695	-0.501	-0.352
1990	-0.305	0.662	-0.311	-0.304	1.659	-0.358	-1.796	-0.014	0.541	-0.452	1.002	-0.352
1991	-0.305	-0.261	-0.311	-0.304	-0.259	-0.934	0.235	-0.901	-1.279	-0.695	-0.501	-0.352
1992	-0.305	-0.261	-0.311	-0.304	-0.259	1.289	-0.753	0.635	1.169	0.161	-0.501	-0.352
1993	-0.305	-0.261	2.112	-0.304	-0.259	0.862	-0.182	-1.094	-0.036	1.081	-0.501	-0.352
1994	5.225	-0.261	-0.311	-0.304	-0.259	2.351	0.738	-0.432	-0.489	-0.695	-0.501	-0.352
1995	0.906	-0.261	-0.311	-0.304	-0.259	-1.174	0.374	-0.578	-0.333	-0.178	-0.501	-0.352
1996	0.704	-0.261	-0.311	-0.304	-0.259	-0.507	-0.102	-0.492	-1.255	2.519	-0.501	-0.352
1997	0.926	-0.261	-0.311	0.922	0.215	0.238	-1.278	-0.328	-0.605	-0.381	0.770	0.596
1998	-0.305	-0.261	-0.311	-0.304	-0.259	-0.982	0.070	-0.518	0.912	1.169	1.721	-0.352
1999	-0.305	1.489	-0.311	-0.304	0.012	0.083	-1.023	-1.120	-0.767	2.930	-0.501	-0.352
2000	-0.305	-0.261	-0.311	-0.304	0.295	-0.768	0.359	-0.166	-1.337	-0.695	-0.501	0.874
2001	-0.305	-0.261	-0.311	-0.304	-0.204	0.744	-0.631	1.753	-1.025	-0.533	-0.501	-0.352
2002	-0.305	-0.261	2.112	1.739	-0.259	0.607	-1.937	0.254	-0.567	-0.695	-0.501	-0.051
2003	-0.305	5.573	-0.311	-0.304	-0.259	1.638	1.559	0.134	-0.519	-0.673	-0.501	-0.352
2004	-0.305	-0.261	-0.311	-0.304	0.037	0.209	1.306	0.668	-0.610	-0.444	-0.501	-0.352
2005	-0.305	-0.261	-0.311	-0.304	-0.259	3.774	-0.605	-0.101	0.542	-0.695	-0.501	-0.352
2006	-0.305	-0.261	-0.311	-0.304	-0.259	0.406	1.144	-0.328	-0.745	-0.134	-0.501	-0.352
2007	0.098	-0.261	-0.311	-0.304	-0.259	-0.499	-0.274	0.986	0.293	-0.695	-0.052	-0.352
2008	-0.305	1.683	-0.311	-0.304	-0.259	-0.660	0.313	1.546	0.507	-0.538	-0.501	0.175
2009	-0.305	-0.261	-0.311	-0.304	-0.259	-1.053	1.270	-0.669	-0.228	1.192	0.860	-0.352
2010	-0.305	-0.261	-0.311	-0.304	-0.259	-0.143	-0.335	1.463	1.452	0.046	1.875	-0.352
2011	-0.305	-0.261	-0.311	-0.304	-0.039	-0.956	-0.533	1.492	0.179	-0.668	-0.501	-0.352
2012	-0.305	-0.261	-0.311	-0.304	-0.005	-0.603	-1.201	-0.656	1.611	-0.426	-0.501	-0.352
2013	-0.305	-0.261	-0.311	2.964	-0.242	1.055	0.541	0.016	1.737	0.316	-0.501	-0.352
2014	2.520	-0.261	-0.311	-0.304	-0.259	-1.081	0.218	-0.142	0.448	-0.695	3.801	-0.352
2015	-0.305	-0.261	5.074	0.207	-0.259	0.300	-1.043	-1.216	0.745	-0.628	-0.501	-0.352
2016	-0.305	-0.261	0.766	-0.304	-0.259	-0.860	-0.406	-0.515	1.178	1.461	-0.501	-0.352
2017	-0.305	-0.261	-0.311	-0.304	-0.090	-0.040	-0.124	-0.229	-1.006	-0.066	-0.501	2.432
2018	-0.305	-0.261	-0.311	-0.304	-0.259	-0.743	2.001	-0.619	-1.084	-0.695	-0.501	-0.352
2019	-0.305	-0.261	-0.311	-0.304	-0.259	-0.172	-0.504	0.733	2.253	1.439	1.875	-0.352
2020	-0.305	-0.261	-0.311	-0.304	-0.259	-0.755	0.075	3.760	-0.374	-0.583	-0.501	2.583
2021	-0.305	-0.261	-0.311	-0.304	5.837	0.318	-0.720	-0.780	1.003	-0.291	0.205	4.614
2022	-0.305	-0.261	-0.311	-0.304	-0.259	-0.566	1.092	0.700	1.815	0.967	-0.501	-0.352
2023	-0.305	-0.261	-0.149	4.803	-0.259	0.004	1.522	-1.320	0.010	-0.695	2.196	-0.352

Table 7 Season wise SPI value in Navsari area

Year	Winter	Pre-Monsoon	Monsoon	Post-Monsoon
1984	-0.394	-0.298	-0.371	-0.917
1985	-0.394	-0.251	-1.102	1.883
1986	-0.394	-0.298	-0.579	-0.917
1987	-0.394	-0.298	-1.193	-0.550
1988	-0.394	-0.298	1.371	-0.765
1989	-0.394	-0.221	-0.996	-0.917
1990	-0.029	1.629	-1.148	-0.195
1991	-0.394	-0.298	-1.337	-0.917
1992	-0.394	-0.298	0.998	-0.113
1993	-0.394	-0.106	-0.239	0.753
1994	4.868	-0.298	1.285	-0.917
1995	0.759	-0.298	-0.800	-0.431
1996	0.567	-0.298	-1.121	2.105
1997	0.778	0.230	-1.148	0.063
1998	-0.394	-0.298	-0.335	1.566
1999	0.298	-0.026	-1.530	2.491
2000	-0.394	0.260	-0.823	-0.573
2001	-0.394	-0.243	0.415	-0.765
2002	-0.394	-0.021	-1.081	-0.833
2003	1.911	-0.298	1.730	-0.896

Year	Winter	Pre-Monsoon	Monsoon	Post-Monsoon
2004	-0.394	0.000	1.048	-0.681
2005	-0.394	-0.298	1.750	-0.917
2006	-0.394	-0.298	0.482	-0.389
2007	-0.010	-0.298	0.183	-0.769
2008	0.374	-0.298	0.862	-0.622
2009	-0.394	-0.298	-0.145	1.305
2010	-0.394	-0.298	1.069	0.561
2011	-0.394	-0.077	-0.020	-0.892
2012	-0.394	-0.043	-0.746	-0.664
2013	-0.394	-0.145	1.664	0.033
2014	2.295	-0.298	-0.298	0.498
2015	-0.394	0.149	-0.827	-0.854
2016	-0.394	-0.213	-0.470	1.110
2017	-0.394	-0.128	-0.652	0.456
2018	-0.394	-0.298	0.157	-0.917
2019	-0.394	-0.298	0.917	1.871
2020	-0.394	-0.298	1.395	0.012
2021	-0.394	5.829	-0.273	1.089
2022	-0.394	-0.298	1.563	0.646
2023	-0.394	-0.072	0.347	-0.030

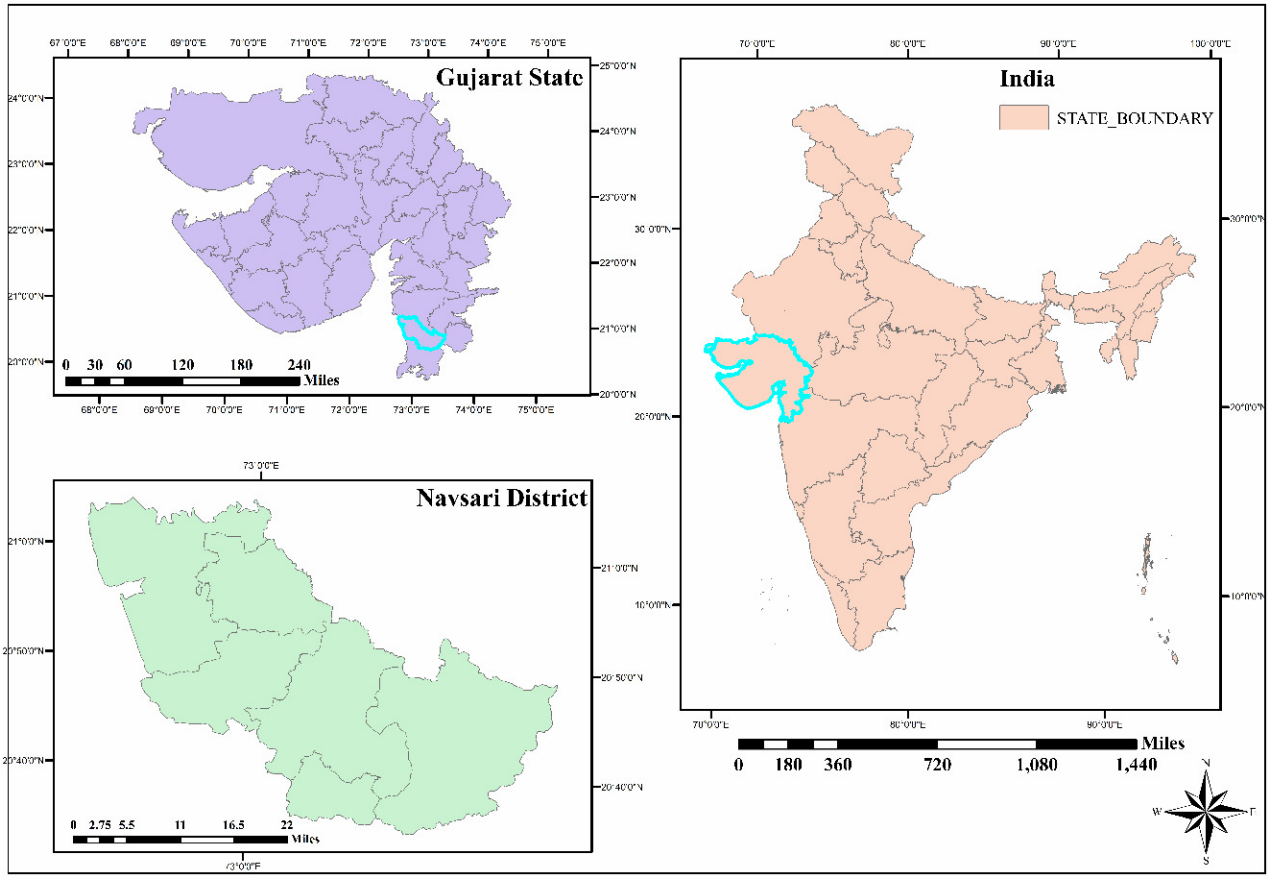

Fig. 1 : Study area

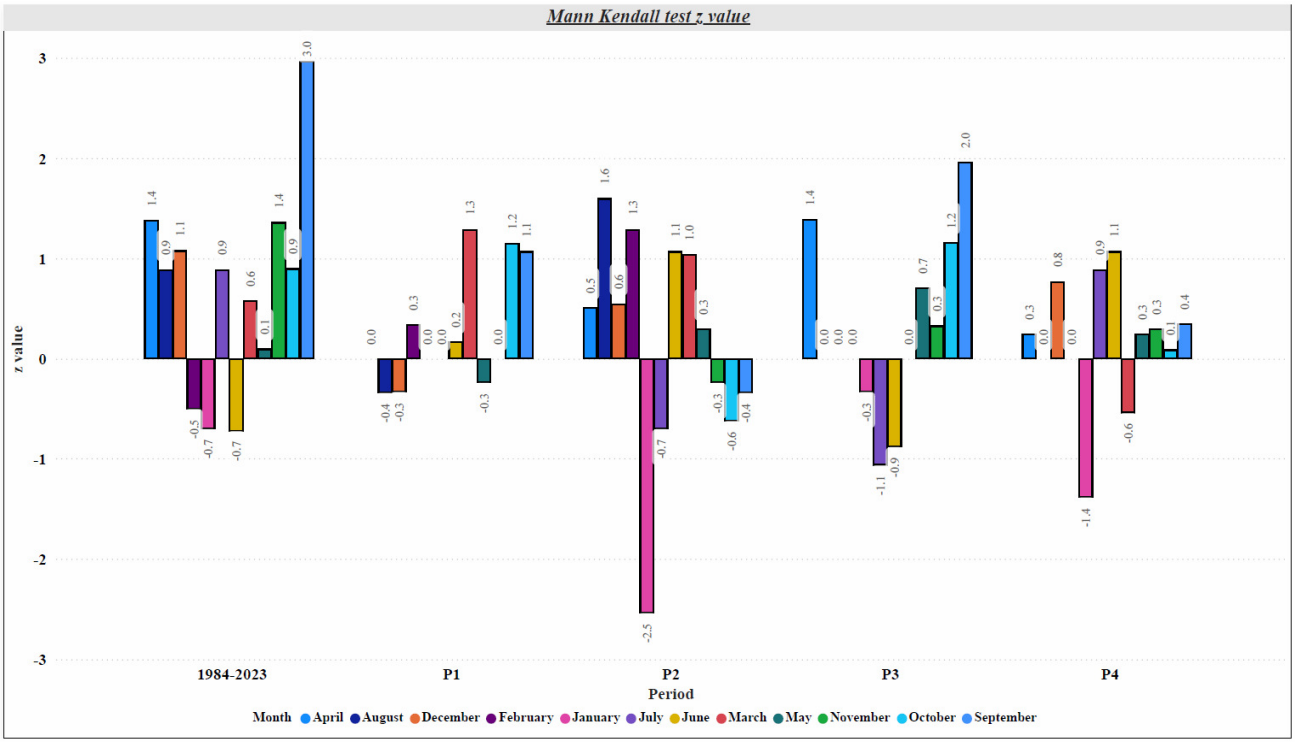

Fig. 2 : Mann-Kendall test month wise z-statistics value of Navsari area

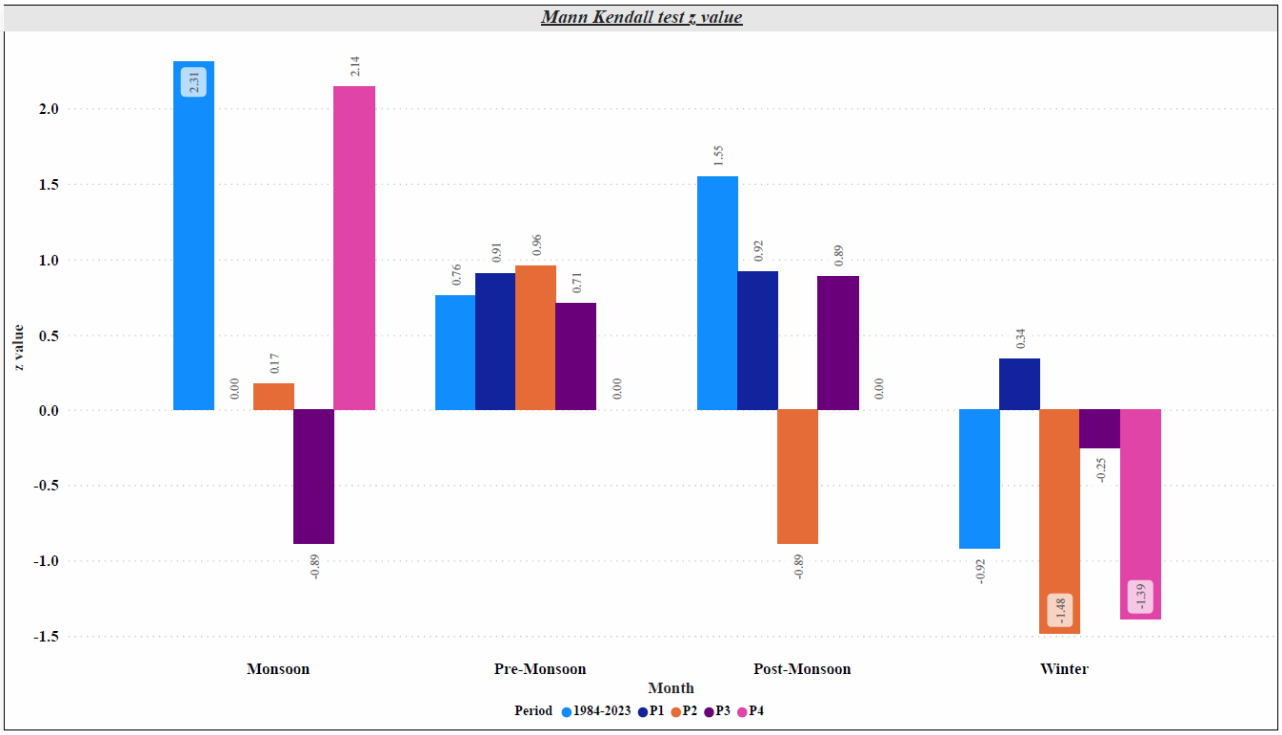

Fig. 3 : Mann-Kendall test season wise z-statistics value of Navsari area

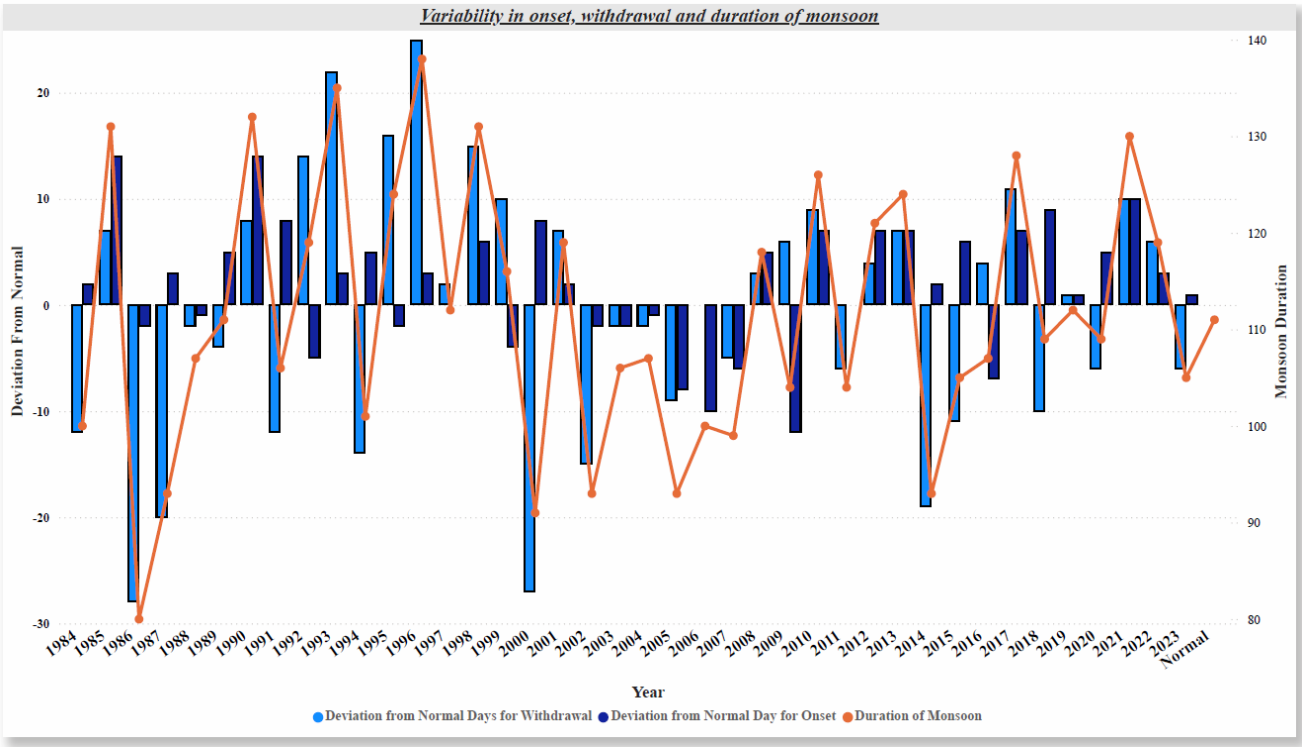

Fig. 4 : Variability in onset of monsoon, withdrawal of monsoon and duration of monsoon in Navsari

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Author statement

The contents and views expressed in this research paper/article are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

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