

Annual and seasonal spatio-temporal analysis of rainfall gridded data (1950-2023) over Darna River Basin, India

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Abstract

The present paper attempts to analyse the rainfall distribution, variability, and trends in annual and seasonal scales over the DRB, India. The high-resolution ($0.25^\circ \times 0.25^\circ$) daily gridded datasets for 74 years (1950-2023) have been procured from the India Meteorological Department (IMD). To assess the basic trends of the rainfall data, statistical techniques such as standard deviation (SD), non-parametric method Mann–Kendall (MK) trend test, and Sen's Slope Estimator (SSE) have been performed for annual and seasonal scales. In addition to understanding the station-wise temporal rainfall change (%), and departure from the mean of the annual and seasonal rainfall data has been computed for further analysis. Lastly, all thematic maps have been prepared by using the inverse distance weighted (IDW) technique in the GIS environment. The study revealed that the CV in the case of the winter season was computed the highest, 521% at Wasali, followed by 400 % in pre-monsoon at Asvali, indicating high variability of rainfall. The annual trend shows that a significant increasing trend was observed towards the east part at Asvali ($Z=3.35$) and Wasali ($Z=2.74$) rain gauge stations than the west. Likewise, a significant increasing trend was noted (at a 99% significance level) in the monsoon season (June-September) at Asvali ($Z=3.30$) and Wasali ($Z=3.02$) as compared to the Igatpuri station. During the pre-monsoon season remarkably significant decreasing trend was noted at Wasali ($Z= -2.39$), whereas no trend was noted in the post-monsoon season at Wasali. It also figured out that the Asvali station recorded rainfall departure from the mean at the annual scale was highest, +221.5% (2005), followed by +150.3% (2008). The approach adopted in this paper will be greatly advantageous for flood and drought risk management and could be helpful for policymakers associated with sustainable water resource and agriculture management.

Keywords: gridded data; trend and magnitude; flood; drought; Darna river basin

Introduction

Rainfall and surface air temperature are two climate variables that are frequently utilized as indicators of global climate change. The recent Intergovernmental Panel on Climate Change (IPCC) report states that global warming has caused the earth's surface temperatures to rise at an unprecedented rate over the past few decades (IPCC 2013). This has affected the

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hydrological cycle as well as precipitation patterns worldwide. Significant variations in the quantity, intensity, frequency, and type of precipitation have been observed worldwide, and these variations typically reflect substantial natural variability. In several locations of the world, significant long-term trends in precipitation levels have been noted (Pai et al. 2014). An increase or decrease in the amount of rainfall may cause flood or drought risk in the world.

The rainfall of the Indian subcontinent is mainly characterized by the monsoon season, and it contributes more than one-third of the total annual rainfall. Agriculture in the rain-fed area of the country is largely influenced by rainfall and subsequently the total crop production of the country (Vittal et al. 2005). Rivers are major contributors to the rain; from this point of view, rainfall trends were studied for India's various river basins. The Mahanadi and Krishna basins rainfall trend studied by Kumar and Jain (2010) indicates an increasing trend in annual rainfall and a decreasing trend in the monsoon season. Taxak et al. (2014) examined seasonal and annual rainfall patterns for the Wainganga basin in central India. Several recent studies using station and gridded rainfall data on daily extreme rainfall events over India (Sen and Balling 2004; Joshi and Rajeevan, 2006; Goswami et al. 2006; Ghosh et al. 2009; Krishnamurthy et al. 2009; Guhathakurta et al. 2011; Guhathakurta et al. 2012; Pai et al. 2014; Meshram et al. 2017; Hamal et al. 2020; Setti et al. 2020; Gautam and Pandey, 2022; Ranjan and Singh, 2022; Kumar et al. 2022). Hartman and Michelsen (1989) created the first gridded daily rainfall data for the Indian subcontinent and subsequently grouped station data into $1^\circ \times 1^\circ$ grid boxes, using IMD daily rainfall data from 1901 to 1970. Krishnamurthy and Shukla (2007 and 2008) studied the gridded data to study the intra-seasonal and interannual variability of rainfall over India. The precise prediction of rainfall variability at various time and spatial scales is also very valuable for water-related sectors. The variation in the timing, distribution, and amount of rainfall, even if on a small scale, can subsequently be a cause of significant impact on society. The majority of hydrological and climatological investigations depend on rainfall datasets.

The required data of rainfall must be accurate and reliable, with easy accessibility for analysis, which is often generated from a network of ground-based rain gauges. However, the majority of developing nations have inadequate and sparsely distributed rain gauge networks, which results in a lack of data (Hughes, 2006; Nanda et al. 2016; Kumar et al. 2017; Kharake et al. 2021; Rincón-Avalos et al. 2022). Establishing and maintaining these networks is typically expensive, especially in isolated or challenging-to-reach areas. Therefore, to solve this problem of authentic data scarcity, gridded rainfall datasets are often used as an alternative (Yeditha et al. 2020; Bhattacharyya et al. 2022; Gautam and Pandey, 2022). The gridded dataset offers improved spatial and temporal resolution, enabling the study of rainfall in remote or inaccessible regions (Su et al. 2008). They offer detailed information that is crucial for comprehending regional changes in rainfall and aids in ongoing rainfall monitoring (Saikrishna et al. 2021). Most of the gridded datasets are free of cost and easily accessible without restriction in real or near real-time (Kumar and Singh, 2023). The gridded datasets have significantly improved the studies involving climate change, flood, and drought monitoring, etc. (Yeditha et al. 2022). At the micro-watershed level, high-resolution gridded datasets (such as IMD gridded products or satellite-derived GPM/IMERG) offer the continuous spatial coverage required to identify "hotspots" of decreasing rainfall or increasing runoff. The DRB has been selected as a study area for gridded rainfall data analysis, as it offers a representative

micro-watershed of the Nashik district of Maharashtra with varied topography and the influence of Western Ghats on rainfall patterns, with severe water management requirements for irrigation and flood control in Nashik, India. Gridded data analysis for the DRB is essential for flood and drought risk assessment, and sustainable water management, etc. Therefore, the objective set for the present study is to analyse the high-resolution daily gridded long-term data over DRB, India, at the annual and seasonal scale. For this persistence, a newly developed daily gridded rainfall dataset of higher spatial resolution ($0.25^\circ \times 0.25^\circ$, latitude \times longitude) covering a longer period of 74 years (1950-2023) over the Indian mainland (Pai et al. 2014) was used. Similarly, the spatio-temporal change is assessed station-wise to study the rainfall distribution, variability, trend, and magnitude of trend at annual and seasonal scales of DRB, to understand the rainfall outline. This kind of study is useful for planners and managers working in water-related fields such as agriculture, hydrology, water resource management, etc. Henceforth, the study is also useful in flood forecasting, climate modelling, sustainable water resources management, agriculture, and urban planning, etc.

Study area

The Darna River is a tributary of the Godavari River, located in the Nashik district of Maharashtra, India. The river rises at an elevation of 1040 m in the Kulung hill of the Sahyadri range, and it covers a total area of about 1316.42 km². The Darna River Basin (DRB) is extended between 19⁰ 35' 00" N to 19⁰ 59' 13" N latitudes and 73⁰ 31' 31" E to 73⁰ 58' 46" E longitudes (Fig. 1). Total of 9 grids and 3 IMD rain gauge stations, namely Igatpuri, Asvali, and Wasali, are depicted in the DRB. Details of all the stations have been mentioned in Table 1 and Figure 1.

Table 1 IMD rain gauge stations in the Darna River Basin

Sr. No.	Name of the rain gauge station	Latitude	Longitude
1	Asvali	19°41'45.14" N	73°33'39.98" E
2	Igatpuri	19°49'12.65" N	73°43'3.50" E
3	Wasali	19°37'54.20" N	73°43'48.53" E

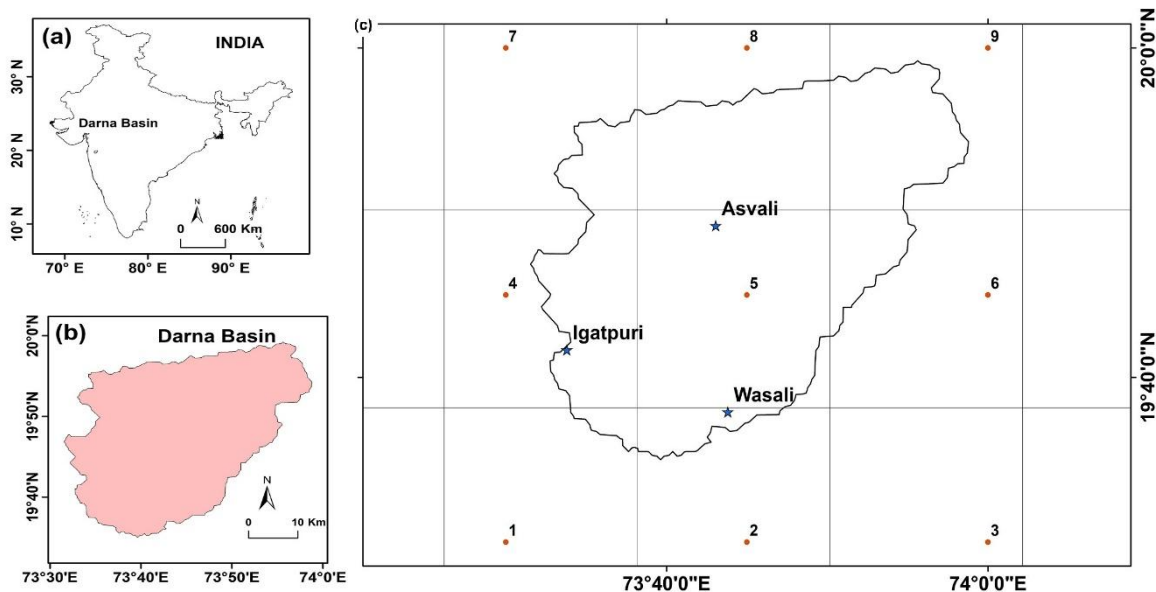


Fig. 1 Location map with grids and IMD rain gauge stations

The Western Ghats greatly influence the distribution of rainfall in the DRB, foremost to high rainfall in the western part, and it decreases and becomes more erratic towards the eastern part of the basin. The mean monsoon rainfall has been documented as 2656 mm, and the mean annual temperature ranges between 18°C and 38°C (Pathare et al. 2024). The DRB is primarily part of the Great Deccan Trap, which is composed of basalt rock, formed by volcanic eruptions. The basin area consists of highly rugged and dissected topography and is covered with alluvial soil. The study area is generally associated with monsoonal deciduous vegetation (Pathare, 2018; Pathare and Pathare, 2020).

Data and methodology

The high-resolution daily gridded datasets at $0.25^\circ \times 0.25^\circ$ resolution for 74 years (1950-2023) have been procured from the India Meteorological Department (IMD). The grid points have been extracted for the Darna River basin. The IMD enlisted 3 rain gauge stations, namely, Igatpuri, Asvali, and Wasali, which are depicted inside the basin. The gridded datasets have been evaluated based on IMD seasonal classification, such as pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-December), winter season (January-February), and annually for the analysis of the long-term rainfall spatial and temporal trends for all 3 stations (Attri and Tyagi, 2010; Pawar, 2022; Yue and Hashino, 2003). The descriptive statistics, such as mean, standard deviation (SD), and coefficient of variation (CV) of rainfall for annual and seasonal scales, have been computed. The statistical implication of the trend in the time series has been analysed by applying the Mann-Kendall (MK) test (Mann, 1945; Kendall, 1975). Similarly, the amount of the trend in the seasonal and annual series has been determined by performing Sen's estimator (Sen, 1968). The station-wise analysis of temporal rainfall change (%) of the annual and seasonal rainfall data has been computed by applying the following formulas, and the computed results are presented in Tables 2 and 3, respectively, for further analysis. A detailed methodology for spatial and temporal rainfall variability, trend, magnitude of trend, and rainfall change analysis is as follows.

Standard deviation (SD) and Coefficient of variation (CV)

The SD of the 74-year rainfall data has been computed using Eq. 1 (Pathare et al. 2025). Similarly, to understand the rainfall variability of DRB, the annual and seasonal level CV has been calculated using Eq. 2 and presented in Table 1 (Landsea and Gray, 1992; Muthoni et al. 2019; Onyutha, 2021).

$$SD = \sqrt{\frac{\sum(x-\bar{x})^2}{n}} \quad (1)$$

$$CV = \frac{SD(\sigma)}{\text{Mean}(\mu)} * 100 \quad (2)$$

The CV classification denoted by Hare (1983) in the classes such as low ($CV < 20$), moderate ($20 < CV < 30$), and high ($CV > 30$) variability, although some scholars (Hare 2003; Asfaw et al. 2018; Alemu and Bawoke, 2020) accepted and modified the classification for the study of the rainfall variability.

Mann–Kendall (MK) test

Before applying the MK trend test on rainfall data to see whether there is a noteworthy correlation, the time series data must be checked for autocorrelation. From that point of view, the PAST software was used to examine the rainfall data using serial autocorrelation, and the results revealed that there was no serial autocorrelation in the data. Therefore, the Mann–Kendall (MK) method was employed to ascertain whether a rainfall trend existed (Hamed and Rao, 1998; Luo et al. 2008; Pawar et al. 2025). The MK is a recurrent and widely applied non-parametric test (Mann, 1945; Kendall, 1975) to check the null hypothesis of no trend against the alternative hypothesis (existence of an increasing or decreasing trend) in time series. Hence, annual and seasonal rainfall trends over the DRB were identified by applying the MK test statistic (S), which is obtained by following equations 3 to 7 (Sharma and Singh, 2017; Asfaw et al. 2018; Duhan and Pandey, 2013; Goyal, 2014; Pathare et al. 2024) and findings presented in Table 2.

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \text{sgn}(X_j - X_k) \quad (3)$$

Where; n is the number of data; X_k and X_j are the data values in the time series, k and j ($j > k$), respectively, and $\text{sgn}(X_j - X_k)$ is the sign function as

$$\text{sgn}(X_j - X_k) = \begin{cases} +1 \text{ if } (X_j - X_k) > 0 \\ 0 \text{ if } (X_j - X_k) = 0 \\ -1 \text{ if } (X_j - X_k) < 0 \end{cases} \quad (4)$$

When; $n \geq 10$, S becomes approximately normal distribution with mean = 0 and variance as follows:

$$\sigma_s^2 = \frac{1}{18} [n(n-1)(2n+5) - \sum_t t(t-1)(2t+5)] \quad (5)$$

Where; t refers to the extent of any given tie and \sum_t indicates the summation of all ties. The value of Z is computed by Equation 6 (Partal and Kahya, 2006).

$$Z = \begin{cases} \frac{s-1}{\sigma_s} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{s+1}{\sigma_s} & \text{if } S < 0 \end{cases} \quad (6)$$

Where; Z is the standard normal variate, positive (negative) values of Z indicate increasing (decreasing) trends. A null hypothesis is rejected when $|Z| > Z_{1-\alpha}$ – and a remarkable trend occurs in the time series. The outcomes of the study are tested at $\alpha = 0.05$ ($Z = \pm 1.96$) and $\alpha = 0.01$ ($Z = \pm 2.576$) significance levels (Pawar, 2022).

Sen's slope estimator (SSE)

The magnitude of the trend/slope (β) in the seasonal and annual series was quantified by using Eq. 7 (Sen, 1968).

$$\beta = \text{median} \left(\frac{x_j - x_i}{j - i} \right) \quad (7)$$

Where β represents the median value of the slope value between data measurements x_i and x_j at the time steps i and j ($i < j$), respectively. The positive value of β indicates an increasing trend, whereas the negative value indicates a decreasing trend.

Rainfall magnitude change as a percentage of the mean

The rainfall magnitude change as a percentage of the mean is a statistical metric that expresses the relative increase or decrease of rainfall over a specific period or in a particular location, compared to its long-term mean. To understand the temporal climate variability, the percentage change in the magnitude of rainfall has been computed by using Eq. 8 (Mondal et al. 2015; Pawar, 2022).

$$\text{Percentage Change (\%)} = \frac{\beta * \text{length of year}}{\text{mean}} * 100 \quad (8)$$

Lastly, based on all the computed results, the average, CV, trend, and amount of trend of rainfall change maps have been prepared by using the inverse distance weighted (IDW) technique in the GIS environment for a better understanding of the spatial distribution and variability. Likewise, the temporal analysis is shown by graphical methods.

Result and discussion

Spatial analysis of the distribution and variability of rainfall

The Mean, SD, and CV (%) of seasonal and annual rainfall during the period 1950 to 2023 are given in Table 2. The mean annual rainfall over the DRB was recorded as the highest at the Igatpuri rain gauge station (3134mm) with SD of 847 mm and CV of 27 % indicating moderate annual rainfall variability, while the lowest mean annual rainfall was recorded at Asvali (1013mm) with SD of 467 mm and CV of 46 % indicating high variability of rainfall (Fig. 2a).

The mean monsoon rainfall ranged between 3045mm and 923mm at the Igatpuri and Wasali rain gauge stations, respectively (Fig. 2c). The winter season was recorded mean rainfall between 1.6 mm (Wasali) to 2.4 mm (Asvali), which highlights very low rainfall received in the winter season in the DRB. The seasonal rainfall distribution shows that the pre-monsoon, post-monsoon, and winter seasons show very low distribution of mean rainfall compared to monsoon and annual mean rainfall (Fig. 2b,d,e). These results indicate that the rainfall decreases from west to east of the DRB due to the topographic arrangements of the Western Ghats, in addition to the monsoonal progress that starts from the west and proceeds to the east. Similar outcomes were reported by Biswas et al. (2019) and Pathare et al. (2024) in their research work.

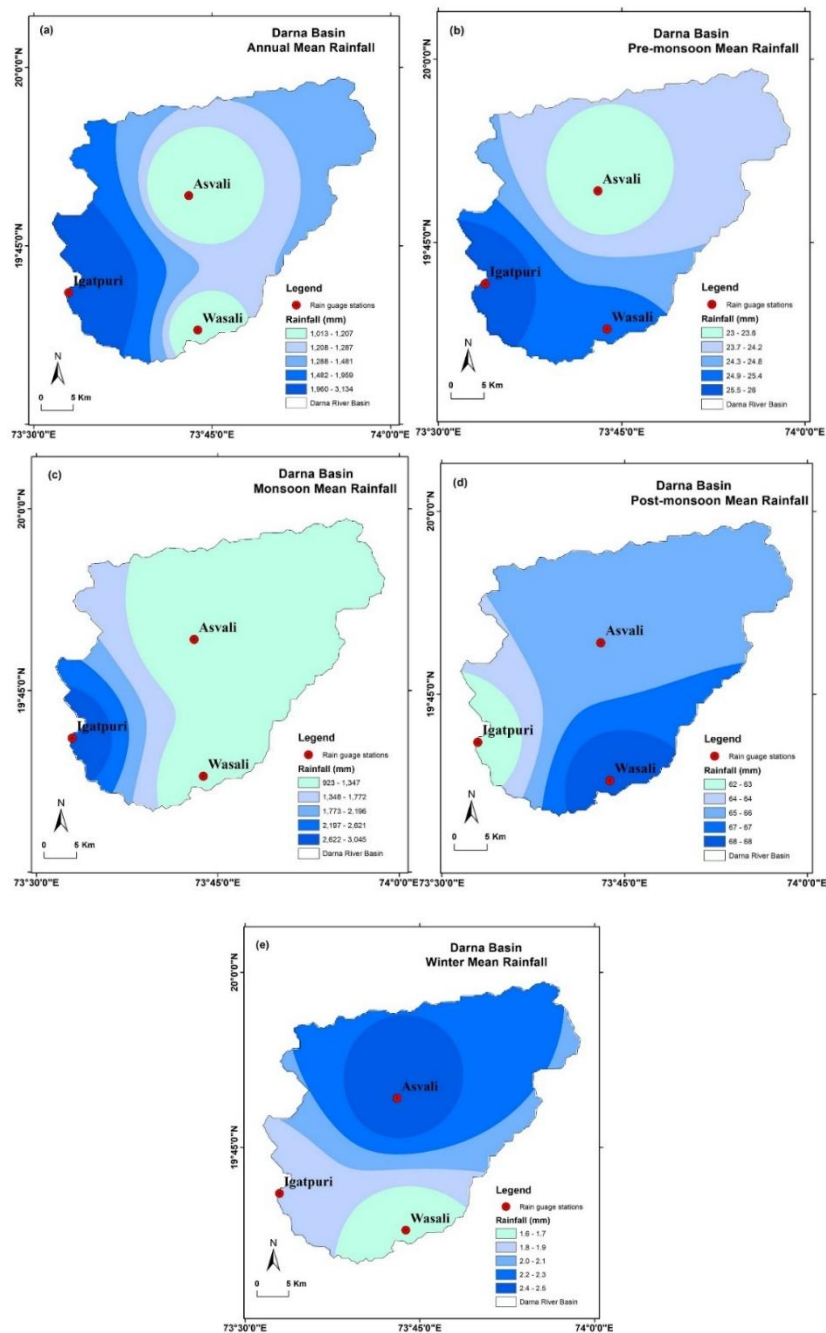


Fig. 2 Annual and Seasonal rainfall distribution over the DRB

Table 2 Summary of the annual and seasonal rainfall of the Darna River Basin (1950-2023)

Period/Time	Stations	Max (mm)	Min (mm)	Mean (mm)	SD(mm)	CV (%)
Annual	Asvali	3257	450	1013	467	46
	Igatpuri	5389	1115	3134	847	27
	Wasali	3316	348	1078	500	46
Pre-monsoon	Asvali	171	0	23	31	400
	Igatpuri	364	0	26	50	190
	Wasali	178	0	25	34	135
Monsoon	Asvali	3235	434	923	455	49
	Igatpuri	5295	950	3045	838	28
	Wasali	3293	348	983	486	49
Post-monsoon	Asvali	274	0	65	60	92
	Igatpuri	241	0	62	61	98
	Wasali	342	0	68	73	106
Winter	Asvali	64	0	2.4	8	349
	Igatpuri	45	0	1.8	7	360
	Wasali	71	0	1.6	8	521

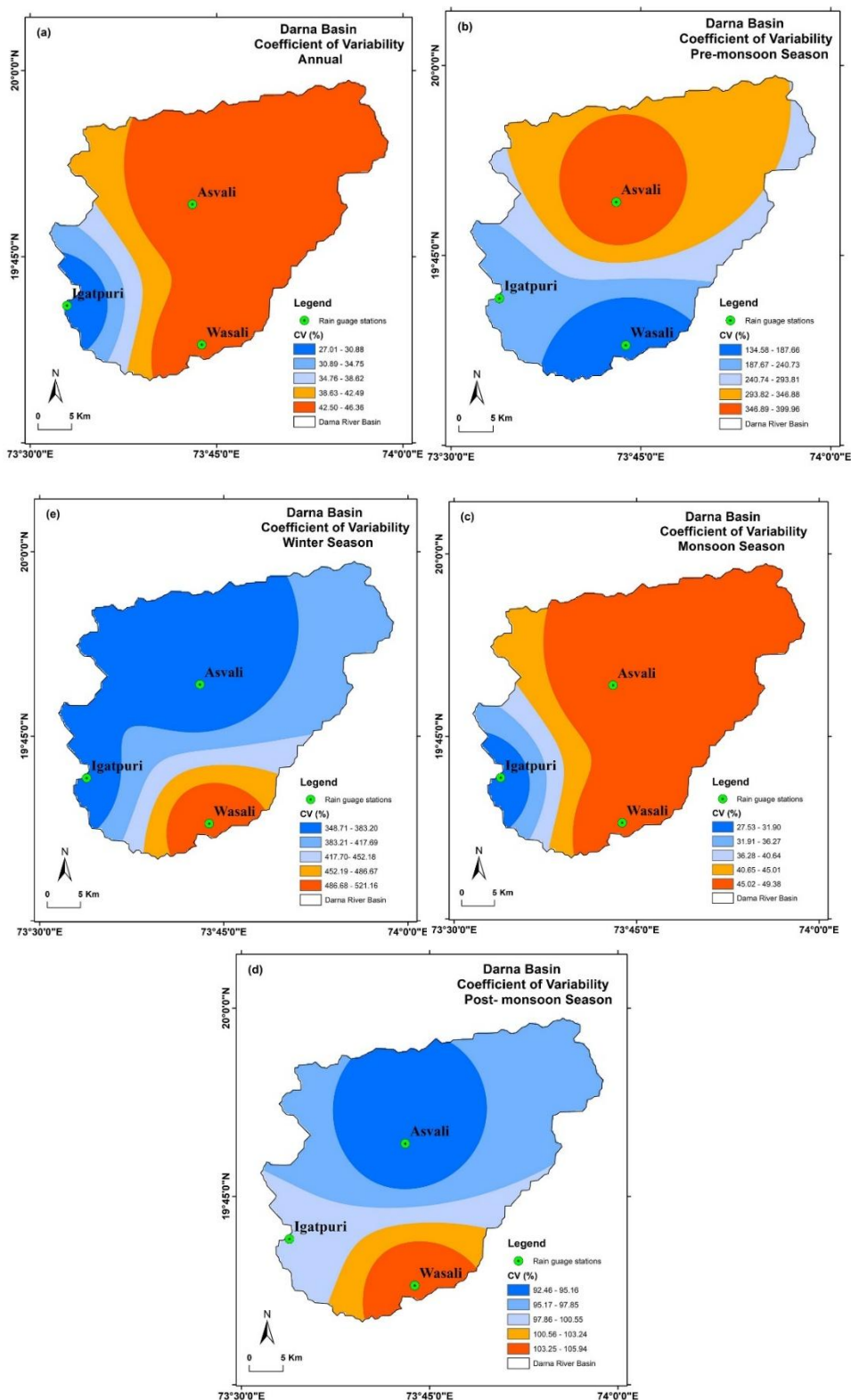


Fig. 3 Annual and Seasonal rainfall variability over the DRB

Spatial analysis of the rainfall trend by the MK test

The MK test and SSE techniques were applied to determine the type and amount of rainfall trend over the DRB for the period of 1950-2023, and the results were compiled in Table 3. The annual trend of the spatial distribution of DRB, shows that a significant increasing trend was

observed towards the east part at Asvali ($Z=3.35$) and Wasali ($Z=2.74$) rain gauge stations than the west (Fig. 4a). Likewise, a significant increasing trend was noted (at a 99% significance level) in monsoon season (June-September) at Asvali ($Z=3.30$) and Wasali ($Z=3.02$) as compared to Igatpuri station (Fig. 4c). During the pre-monsoon season remarkable significant decreasing trend was noted at Wasali ($Z= -2.39$), whereas, no trend was noted in the post-monsoon season at Wasali and insignificant decreasing trend ($Z= -0.07$) were noted at Igatpuri. The winter season shows an insignificant increasing trend for all stations over the DRB (Fig. 4b,d,e). Overall, there are significant positive trends observed for the Asvali station during the monsoon season and annual scale. Nevertheless, significant decreasing trends and no trend in rainfall during the pre-monsoon and post-monsoon seasons were observed at Wasali, respectively.

Table 3 Result of Mann–Kendall test, Sen’s Slope and rainfall change (%) period of 1950-2023

Period/Time	Rain Gauge Stations	MK (Z)	SSE (β)	Change (%)
Annual	Igatpuri	0.59	3.09	7.30
	Asvali	3.35**	6.19	45.21
	Wasali	2.74**	6.39	43.86
Pre-monsoon	Igatpuri	- 0.04	0.00	0.00
	Asvali	- 1.33	- 0.07	- 64.75
	Wasali	- 2.39*	- 0.19	-56.24
Monsoon	Igatpuri	0.63	3.32	8.07
	Asvali	3.30**	5.74	46.02
	Wasali	3.02**	6.96	52.39
Post-monsoon	Igatpuri	- 0.07	0.00	0.00
	Asvali	0.92	0.20	22.77
	Wasali	0.00	0.00	0.00
Winter	Igatpuri	0.99	0.00	0.00
	Asvali	1.10	0.00	0.00
	Wasali	0.89	0.00	0.00

*Significant at 95% confidence level; **Significant at 99% confidence level

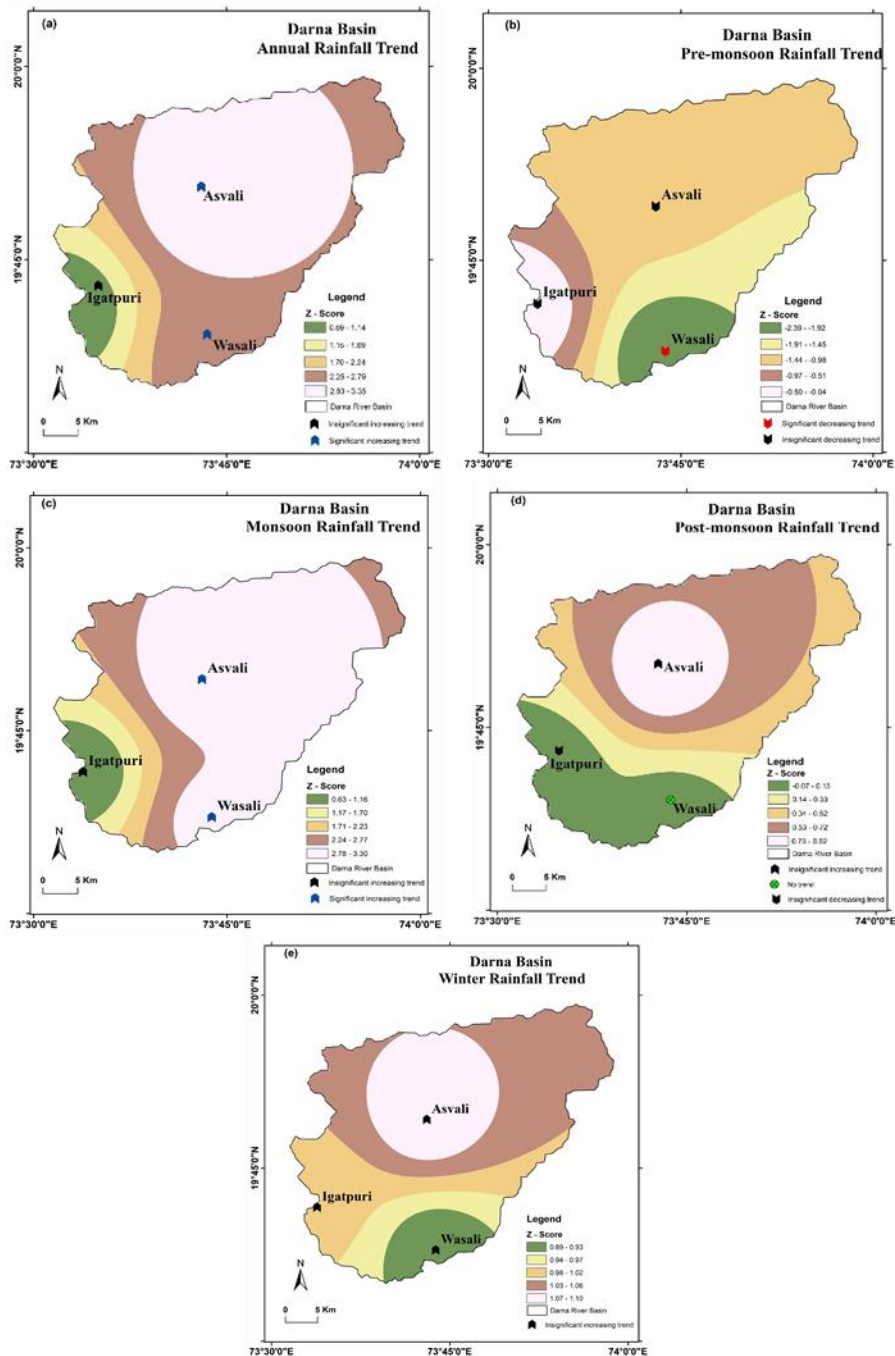


Fig. 4 Annual and seasonal rainfall trends over the DRB based on MK test

Analysis of the rainfall magnitude change

The computed rainfall magnitude change analysis of DRB interpreted that the annual scale was verified between 7.30% at Igatpuri and 45.21% at Aswali, whereas the monsoon rainfall magnitude change varied between 8.07% (Igatpuri) and 52.39% (Wasali) (Table 3; Fig. 5a, c). A significant positive change was observed at Wasali in the monsoon season, followed by Aswali (46.02%) in the monsoon season, and a significant negative change was noted at Wasali (-56.24%), followed by an insignificant decreasing change at Aswali (-64.75%) in the pre-monsoon season (Fig. 5b).

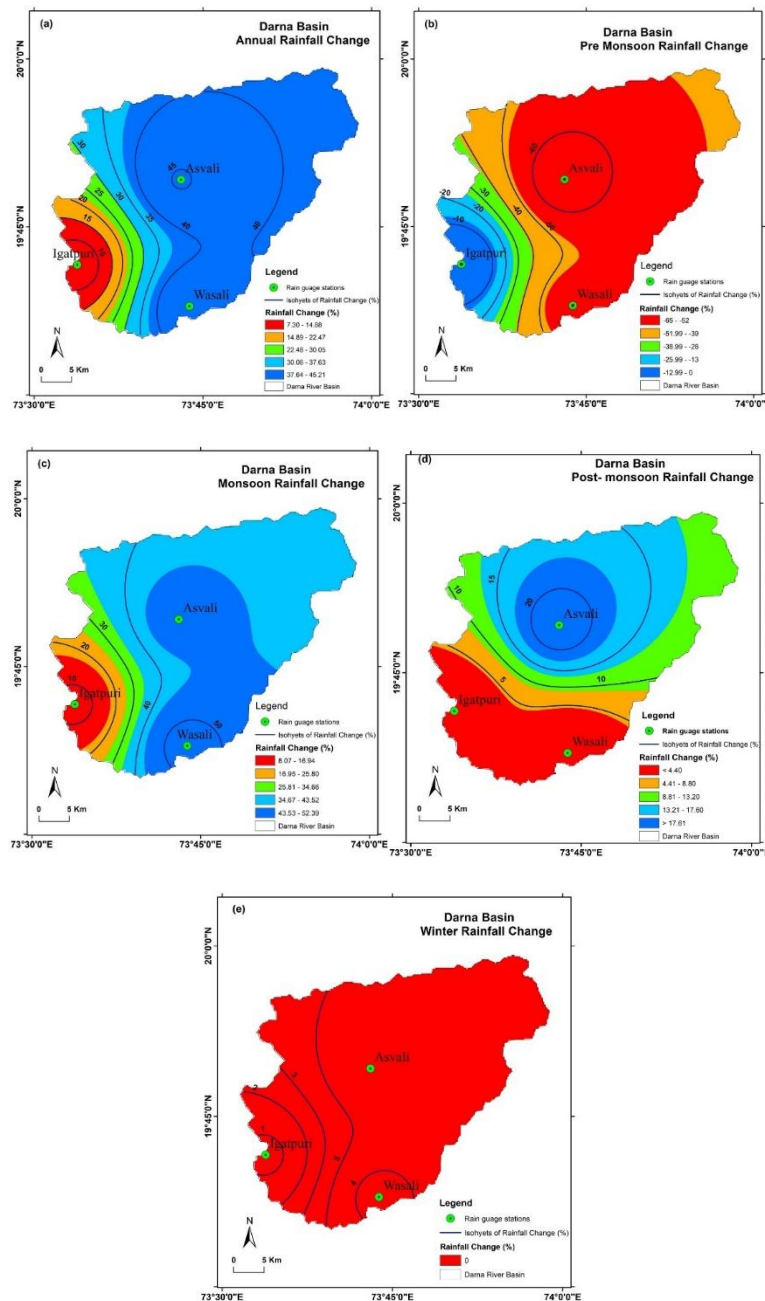


Fig. 5 Annual and seasonal rainfall magnitude change over the DRB based on SSK

Excluding the annual (7.30%) and monsoon scale (8.07%), the Igatpuri station was noted that no change in rainfall magnitude over the DRB at the pre, post-monsoon and winter seasons in the given period (Fig. 5b,d). The winter season was thoroughly noted, and all stations documented no change in the amount of rainfall in the current study (Fig. 5e). Overall, the outcomes of the rainfall magnitude change were notable during monsoon and annual scale. The rainfall result indicates that the DRB was greatly influenced by the dominance of the monsoon season.

Spatial-Temporal analysis of the departure of rainfall

The most notable characteristic of India's monsoon-dominated regions is the seasonal and annual variation in rainfall (Rajeevan and Francis, 2007). The study of variability of rainfall,

both on seasonal and annual scales, may negatively impact farmers' ability to mitigate the effects of climate variability. From this point of view, rainfall departure from the mean analysis was executed station-wise and season-wise for the DRB.

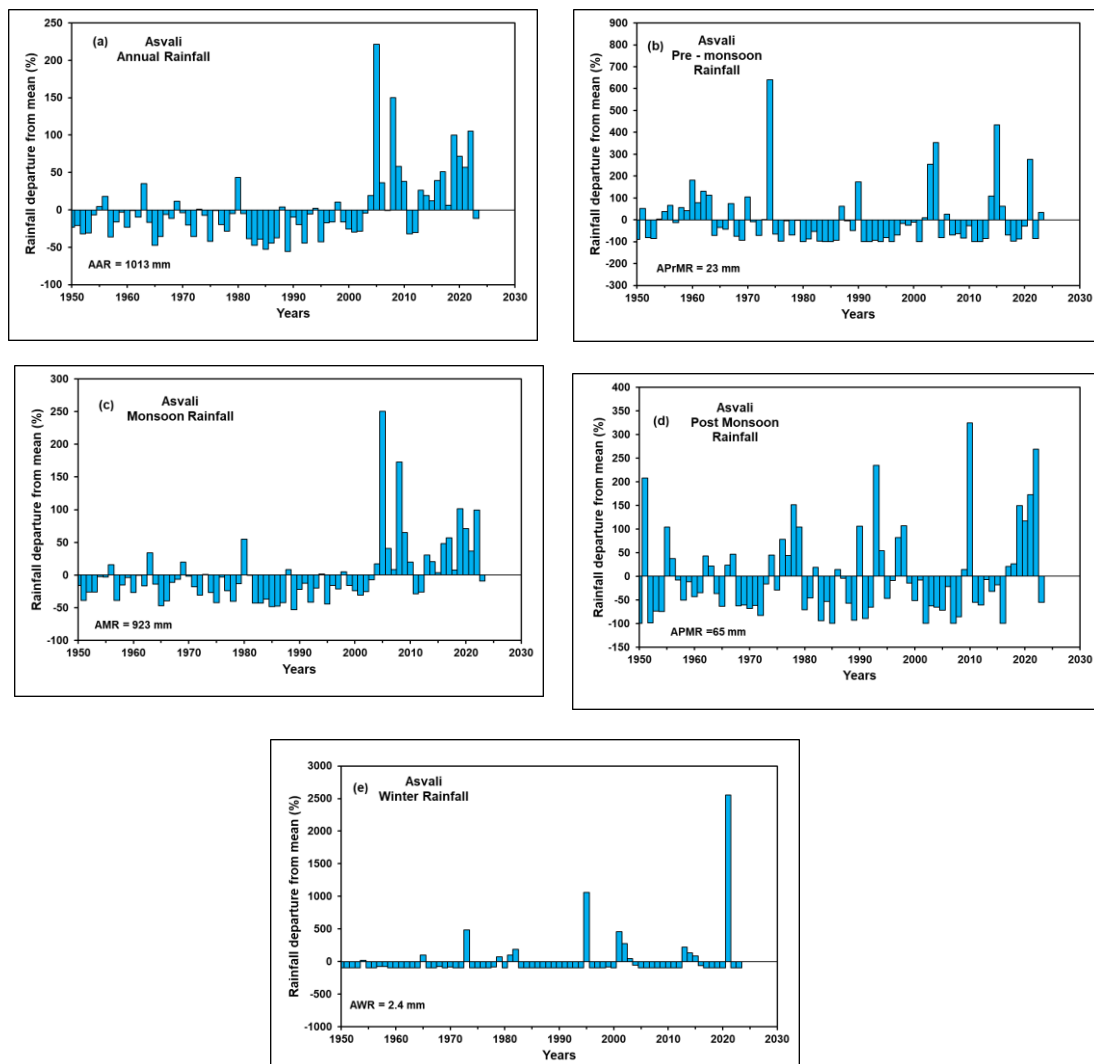


Fig. 6 Annual and seasonal analysis of the departure of rainfall at Asvli (1950-2023)

The Asvli station recorded rainfall departure from the mean at the annual scale was highest, +221.5% (2005), followed by +150.3% (2008), and the lowest value, -55.6% (1989). In the pre-monsoon season, +640.2% (1974) and 100% (1980, 1984, 1985, 1991, 1992, 1996, 2001, 2011, 2012) rainfall departure from the mean was recorded. The monsoon season's highest value was +250.5% (2005), and the lowest was recorded at -53% (1989). The highest values of annual and monsoon seasons were recorded in the years 2005 and 2008, which also supports that these years also witnessed floods over the DRB. In the post-monsoon season at Asvli station, the documented highest rainfall departure from the mean was +324.9% (2010), and the lowest was -100% (2007, 2016). In the year 2021, the highest departure value from the mean was recorded at +2555.3% and most of the years associated with -100% which was recorded as the lowest value of the Asvli in DRB (Fig 6a-e).

The Igatpuri rain gauge station documented rainfall departure from the mean at the annual scale was highest, +71.9% (2019), and lowest, -64.4% (1962). In the pre-monsoon season, rainfall departure from the mean ranged between +1291.3% (1974) to -100% (1950, 1952, 1969, 1976, 1980-1985, 1991, 1992, 1996, 2001, 2002, and 2011) and was frequently below the average of pre-monsoon rainfall (26 mm) of Igatpuri (Fig. 7a,b). The monsoon (June-September) rainfall over the PRB at Igatpuri station showed rainfall departure from mean, a noteworthy range between + 73.9% (+ 5295 mm) and - 68.8% (950 mm) in the years 2019 and 1962, respectively (Fig. 7c). The highest value of monsoon season at Igatpuri station in the year 2019 also proved that the flood occurred. Figure 7d revealed that the post-monsoon rainfall departure from the mean denoted that rainfall varied between + 290.6% (1951) and - 100% (in 1950, 1885, 1988, 1989, 2007, 2012, and 2016). Figure 7e indicates that the winter rainfall departure from the mean varied between + 2387.2% (in 2021) and - 100% throughout the year at Igatpuri station, which illustrates the greater variation in the winter season (January and February) than the monsoon and annual scale, similarly revealed the monsoon dominance at Igatpuri subsequently over the DRB.

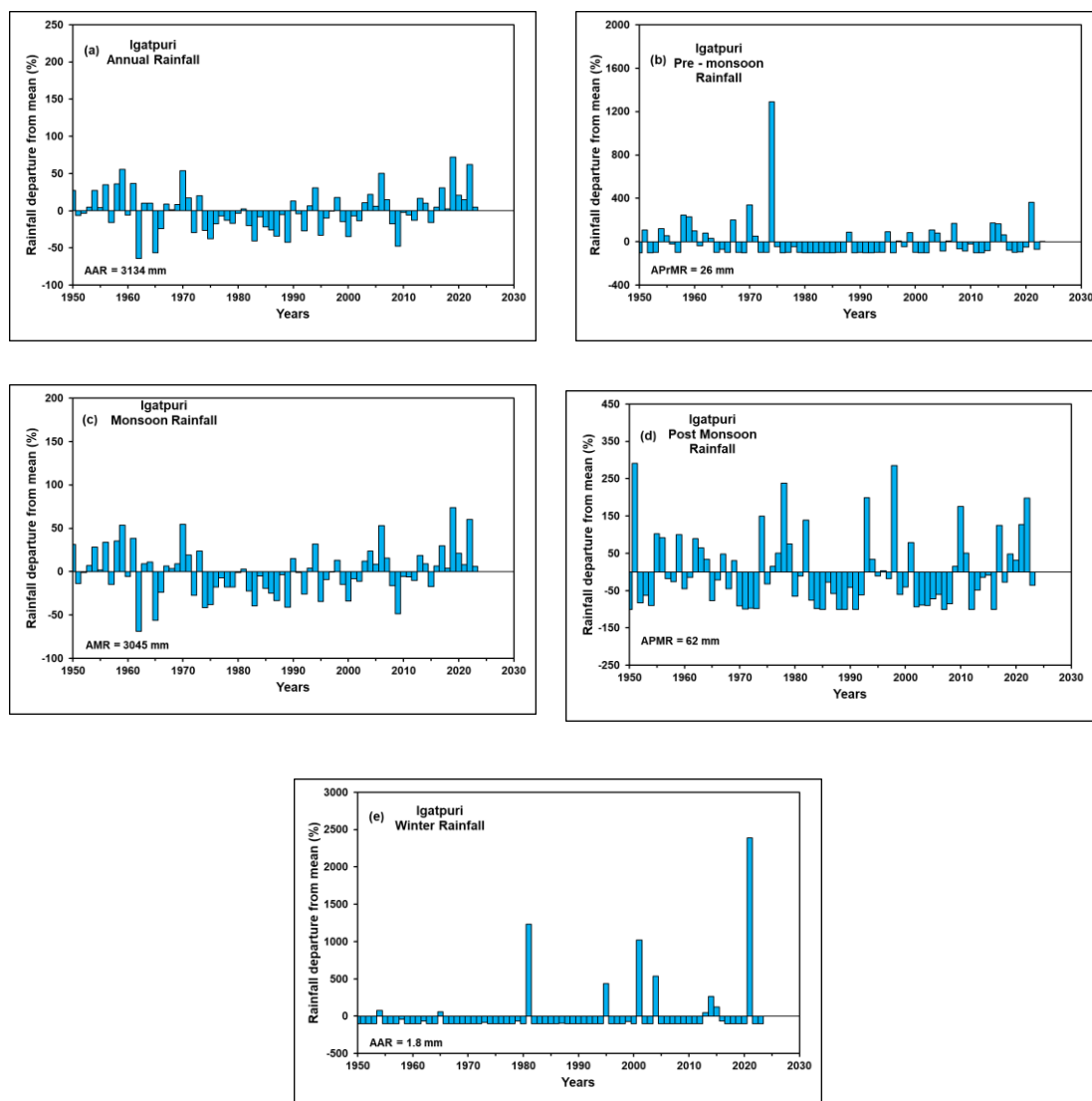


Fig. 7 Annual and seasonal analysis of the departure of rainfall at Igatpuri (1950-2023)

The Wasali rain gauge station in the DRB recorded rainfall departure from the mean at the annual scale was highest +207.5% (3316 mm), and lowest -67.7% (348 mm) in the years 2005 and 1985, respectively (Fig. 8a). Figure 8b interprets the pre-monsoon records of rainfall departure from the mean, which varies from +609.6% (2004) to -100 (1981, 1983-1985, 1989, 1990, 1992, 1994, 1996, 2001, 2011 and 2012). Temporal analysis indicates that most of the years' rainfall falls under average rainfall (25 mm) at Wasali station in March- May (pre-monsoon). The monsoon (June–September) rainfall figures showed noteworthy year-to-year variations in rainfall, and rainfall ranged between + 234.9% (+ 3293 mm) and – 64.6% (348 mm) in the year 2005 and 1985 respectively (Fig. 8c).

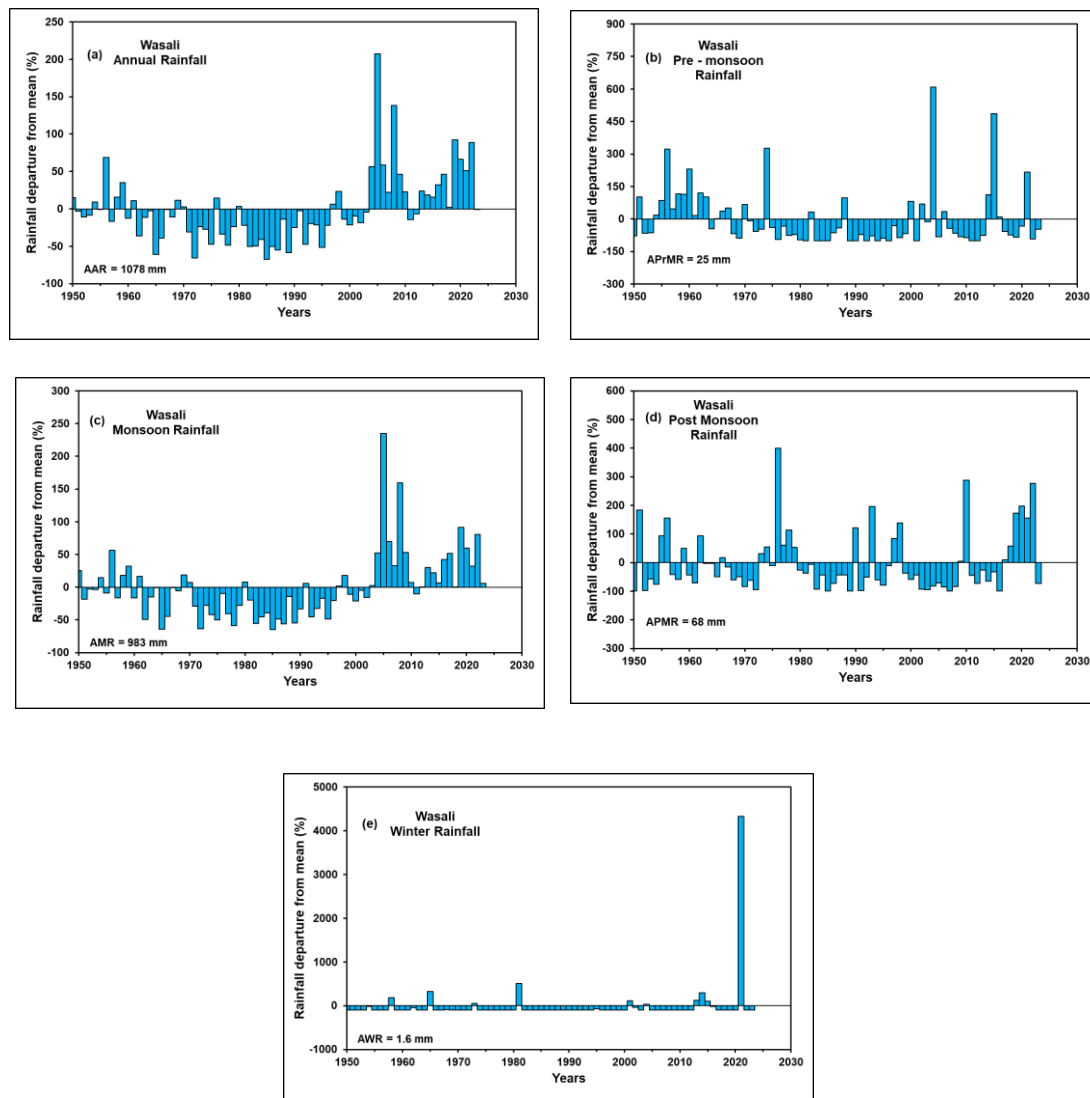


Fig.8 Annual and seasonal analysis of the departure of rainfall at Wasali (1950-2023)

The post-monsoon (October-December) rainfall departure from the mean denoted that rainfall varied between + 399.9% (1976) and -100% (1950, 1985, 1989, 2007, and 2016) over the DRB at Wasali station (Fig. 8d). Figure 8e revealed the rainfall departure from the mean for the winter season and it strongly noted that the more variability of the rainfall observed throughout the year and it below the average (1.6 mm) of Wasali rainfall. An extremely high value was recorded, 4324.4 % (71 mm) in the year 2021.

Conclusion

The current study has investigated rainfall patterns and trends over the DRB at seasonal and annual scales based on 74 years of daily gridded rainfall data. The station-wise rainfall distribution analysis indicated that the DRB receives about 90 % of the rainfall during the monsoon season and 10 % rainfall in the post-monsoon season. The annual trend shows that a significant increasing trend was observed towards the east part at Asvali ($Z=3.35$) and Wasali ($Z=2.74$) rain gauge stations than the west. It shows the great influence of the Western Ghats, especially the western part of the DRB. Likewise, a significant increasing trend was noted in the monsoon season (June-September) at Asvali ($Z=3.30$) and Wasali ($Z=3.02$) as compared to Igatpuri station. During the pre-monsoon season remarkable significant decreasing trend was noted at Wasali ($Z= -2.39$), whereas, no trend was noted in the post-monsoon season at Wasali. The highest value rainfall departure from the mean + 73.9% (+ 5295 mm) of monsoon season at Igatpuri station in the year 2019. This result also proved that the major flood events occurred in the year 2005, 2008 and 2019 in the study area. The 3 rain gauge stations namely; Asvali, Igatpuri and Wasali experienced the same direction of trend in monsoon and annual rainfall. Spatially great variations was noticed all over the DRB, especially in pre, post-monsoon and winter season. Moreover, this study would help to understand the risks and vulnerabilities of flood and drought in the monsoon season and monsoon. The approach adopted in this paper will be greatly advantageous for flood and drought risk management and could helpful for policymakers associated with sustainable water resource and agriculture management.

Declarations

CRedit authorship contribution statement

Jyoti Pathare: Conceptualization, Data analysis and visualization, writing, review, and editing.

Declaration of competing interest

The authors declare no competing interests.

Availability of data and materials

The data sets supporting the results of this article are included in the manuscript.

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