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Spatio-temporal Trends of Rainfall and Rainy Days in Konkan Region of Maharashtra

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The present study aimed to carry out the spatial and temporal trend analysis of annual, seasonal and monthly rainfall and rainy days in the Konkan region of Maharashtra state. Trend analysis was performed for rainfall and rainy days observed at twelve different locations spread over the region. Mann Kendall and Sen's slope test were used to know the nature of trend and its magnitude, respectively and results were tested at 90, 95 and 99% confidence levels. Results showed that significant increasing trend in rainfall ranging from 26.23 to 38.27 mm yr^{-1} was observed at Suksale, Mulde and Bhatsanagar. A decreasing non-significant trend was observed at Karjat and Awalegaon while at remaining locations a non significant increasing trend in annual average rainfall was observed. In most locations the number of rainy days was found to exhibit an increasing non significant trend and only at Wakawali the number of rainy days was significantly increasing @ 0.25 days yr^{-1}. At Karjat and Pali a non-significant decreasing trend in rainy days was observed. Results also illustrated significant trends in monthly rainfall during August, September, November and December. Monthly rainy days also exhibited significant change during May, July, August, September, October and November. Overall, the changes in annual rainfall amount and rainy days were observed in the region. These changes may have further influence on water resource availability for agriculture in the region.

(***Key words:*** *Konkan, Mann-Kendall, Rainfall, Rainy days, Sen's slope, Trend analysis*)

Konkan is a coastal strip parallel to Sahyadri hill ranges, which rises from mean sea level to 300 meter height. Konkan region ranges from 27 to 48 km in breadth and about 720 km in length, from Goa to Tapi river basin. Konkan belt is categorized as a hilly region receiving heavy rainfall with an annual rainfall ranging from 2300 mm to 4100 mm. The region receives 46 per cent of total precipitation of the state on just 10 per cent of total area (Anonymous, 2013). Rainfall is one of the crucial weather parameters for the climate change detection (Sahu and Khare, 2015). Climate change is acting as a trigger for changing rainfall pattern which have significant impacts on hydrological cycle and crop calendar of the region (Abrol *et al*., 2004; Mirza and Hussain 2004). Mono-cropping with rice cultivation during *kharif* season is generally observed, while the horticulture crops like mango, cashew and coconut are major crops of the region. In last few years production, productivity and quality of mango especially *Alphonso* variety was adversely affected due to change in different meteorological parameters in the region (Abhishek, 2017). Most of the crops in the region are rainfed cultivated. Rupa Kumar *et al*. (1992) reported that, rainfall along the West coast of India is increasing on the regional scale. Accurate information of rainfall and its trend is of great importance because of economic implications of rainfall dominated operation (Galkate *et al*., 1999). Thus, it becomes very essential to analyse rainfall for its spatial and temporal variation to manage the crops accordingly. Detection of rainfall trend in the region is also necessary to establish link between rainfall and other hydrological components which can provide useful insights into the possible changes in the hydrology of the region and can be helpful for the decision making in water resource management. Rainfall trends at the smaller spatial scale are more useful for the precision water resource and crop planning. Taking the above considerations the present study was undertaken to analyse the trend of the annual, seasonal and monthly rainfall and rainy days in the Konkan region of Maharashtra.

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MATERIAL AND METHODS

Study area and data collection

The present study was undertaken to know the trends of rainfall and rainy days for which the daily rainfall data of study locations was collected from Department of Agronomy, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra and Water Resource Department, Hydrological Project, Government of Maharashtra, Nasik. Location details, period range of rainfall data and source of data acquisition are tabulated in Table 1 and stations are located on map in Fig. 1. The daily data were converted in to seasonal, *kharif* from 23rd to 41st standard meteorological week (SWM), *rabi* from 42nd to 8th SWM and summer from 9th to 22nd SWM.

The rainy days were calculated by using daily rainfall data. The day receiving ≥ 2.5 mm rainfall was considered as a rainy day. Rainfall and rainy days were arranged in annual, seasonal and monthly time scales and their statistical parameters such as mean, standard deviation and coefficient of variation were determined. Trend analysis was statistically examined in two phases *i.e*., initially the presence of a monotonic increasing or decreasing trend was tested using the non-parametric Mann-Kendall test (Kendall, 1995; Mann, 1945). Then the rate of change was estimated with the help of Sen's slope test (Sen, 1968). The slope of the trend line indicates the rate and direction of change (Choudhury *et al*., 2012; Drapela and Drapelova, 2011; Helsel and Hirsch 2002). The results of the trends were tested at 90, 95 and 99% confidence levels.

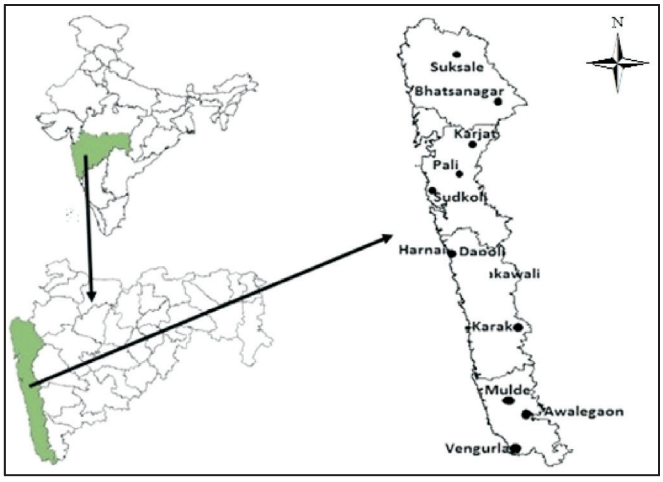

Fig. 1. *Map showing the location of study stations in Konkan region*

Mann-Kendall test (M-K)

If x_1, x_2, …,x_n represent n data points where x_j represents the data point at time j and x_k represent the data point at time k. Then the Mann-Kendall statistic (S) is given by the following formula

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign\,(x_j - x_k) \quad \ldots (1)$$

$$Sign\,(x_j - x_k) = \begin{cases} 1 & if \quad x_j - x_k > 0 \\ 0 & if \quad x_j - x_k = 0 \\ -1 & if \quad x_j - x_k < 0 \end{cases} \quad \ldots (2)$$

Table 1. *Details of station location, period of data for analysis and source of data acquisition*

Sr. No.	Name of location	Latitude	Longitude	Period	Source
1	Suksale	19°55′	73°57′	1982 – 2014	WRDHP, Nasik
2	Bhatsanagar	19°26′	73°48′	1996 – 2014	WRDHP, Nasik
3	Karjat	18°91′	73°33′	1989 – 2014	DBSKKV, Dapoli
4	Pali	18°32′	73°16′	1981 – 2014	WRDHP, Nasik
5	Sudkoli	18°30′	72°59′	1981 – 2011	WRDHP, Nasik
6	Harnai	17°48′	73°50′	1975 – 2008	DBSKKV, Dapoli
7	Dapoli	17°54′	73°18′	1981 – 2014	DBSKKV, Dapoli
8	Wakawali	17°45′	73°17′	1980 – 2015	DBSKKV, Dapoli
9	Karak	16°65′	73°52′	1984 – 2014	WRDHP, Nasik
10	Mulde	16°38′	73°70′	1991 – 2014	DBSKKV, Dapoli
11	Awalegaon	16°26′	73°82′	1982 – 2014	WRDHP, Nasik
12	Vengurla	15°43′	73°42′	1981 – 2011	DBSKKV, Dapoli

WRDHP- Water Resource Department, Hydrological Project, Nashik, Maharashtra
DBSKKV- Dr.Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra

Statistic S was approximately normally distributed with the mean (Drapela and Drapelova, 2011) and variance as follows.

$$VAR(S) = \frac{1}{18}[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5)] \quad \ldots (3)$$

Where,

q = Number of tied groups,

t_p= Number of data values in the p^{th} group.

The standard test statistic Z will be computed as follows

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & if \quad S > 0 \\ 0 & if \quad S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & if \quad S < 0 \end{cases} \quad \ldots (4)$$

The presence of a statistically significant trend was tested using value of Z. A positive/negative value of Z indicates an increasing/decreasing trend. At 90% confidence level, the null hypothesis of no trend is rejected if $|Z| \geq 1.64$; at 95% confidence level, the null hypothesis of no trend is rejected if $|Z| \geq 1.96$; and at 99% confidence level, the null hypothesis of no trend is rejected if $|Z| \geq 2.57$. The significance in trends were denoted as *** for 99% confidence level, ** for 95% confidence level and * for 90% confidence level, respectively.

Sen´s slope estimator

The magnitude of linear trend (change per unit time) was estimated by using a procedure developed by Sen (1968). The slope of trend gave the rate and direction of change for the considered data (Helsel and Hirsch, 2002). This means that linear model f (t) can be described as

$$f(t) = Q_t + B \quad \ldots (5)$$

Where,

Qt = Slope

B = Constant.

To derive an estimate of the slope Qt the slopes of all data pairs was calculated as

$$Q_t = \frac{x_j - x_k}{j-k}, i = 1,2,3 \ldots N, j > k \quad \ldots (6)$$

Where,

xj =Magnitude of sample at j^{th} time;

xk = Magnitude of sample at k^{th} time;

j = Succeeding year of data; and

k = Preceding year of data.

If there are n number of sample values, we get x_j in time series as many as $N = n\ (n - 1)/2$ slope estimates of Q_t. The N number slope values of Q_t were ranked from the smallest to the largest and the Sen's estimator is the median of these N values of Q_t.

$$Q_t = \begin{cases} Q_{\frac{N+1}{2}} & if\ N\ is\ odd \\ \frac{1}{2}\left(Q_{\frac{N}{2}} + Q_{\frac{N+2}{2}}\right) & if\ N\ is\ even \end{cases} \quad \ldots (7)$$

RESULTS AND DISCUSSIONS

Annual variation and trends of rainfall and rainy days

The annual variation of rainfall and its trend in the Konkan region is presented in Table 2. The annual rainfall varied from 2324.8 ± 591.1 mm yr^{-1} at Harnai to 4098.0 ± 599.0 mm yr^{-1} at Karak. The amount of annual rainfall received in northwest and southeast parts of the region was more as compared to northeast and southwest parts. Karak received rainfall more consistently during the last 30 years with least variation of 14.6%, while Harnai showed highest variation of 25.1% among the study locations. Suksale and Mulde exhibited significant increasing trend at 95% confidence level with increase in rainfall at 26.23 and 31.86 mm yr^{-1}, respectively while Bhatsanagar exhibited increasing trend at 90% confidence level with a value of 38.27 mm yr^{-1}. Similar results were obtained by Golekar *et al*. (2016), Jain and Kumar (2012), Naidu *et al*. (1999) and Pulak and Saji (2013). A decreasing, however, non-significant trend was observed at Karjat and Awalegaon while increasing trend in annual average rainfall was observed at the remaining locations.

Annual average rainy days in the region varied from 80.6 ± 9.5 days yr^{-1} at Suksale to 110.8 ± 11 days yr^{-1} at Karak (Table 2). The results in Table 2 also revealed that the number of annual rainy days were more in South Konkan as compared to the Northern part of the region. Coefficient of variation showed the most erratic nature of number of rainy days at Karjat, however, this variation was within 15% at other locations. Significant increasing trend of rainy days

Table 2. *Trend statistics of annual rainfall and rainy days in Konkan region*

Location	Annual Rainfall (mm)					Rainy days				
	Mean	CV	SD	Z	Q	Mean	CV	SD	Z	Q
Suksale	2531.3	20.4	516.2	2.31**	26.23	80.6	11.8	9.5	0.10	0.00
Bhatsanagar	2612.3	21.1	552.5	1.88 *	38.27	87.1	3.0	11.2	0.35	0.18
Karjat	3429.2	21.3	730.1	-0.48	-21.10	90.1	26.5	23.8	-0.60	-0.30
Pali	3464.3	19.7	683.3	0.95	15.61	94.5	10.0	9.4	-0.05	0.00
Sudkoli	3113.6	23.5	732.7	0.53	8.06	89.5	11.8	10.5	0.13	0.03
Harnai	2324.8	25.1	591.1	1.12	9.72	82.4	13.8	11.4	0.64	0.17
Dapoli	3657.9	22.5	824.7	0.11	2.36	98.7	11.3	11.1	1.08	0.27
Wakawali	3732.2	15.8	590.1	1.26	12.63	101.6	9.0	9.1	1.68*	0.25
Karak	4098.0	14.6	599.0	1.37	21.08	110.8	10.1	11.1	1.55	0.29
Mulde	3313.9	15.7	521.6	2.01**	31.86	106.2	9.3	9.9	1.00	0.45
Awalegaon	3706.9	16.2	599.9	-0.03	-1.21	106.8	9.4	10.0	0.03	0.00
Vengurla	2936.9	22.3	654.9	1.1	17.37	95.6	9.7	9.3	1.60	0.31

*Significance at 90% confidence level **Significance at 95% confidence level

@ 0.25 day yr^{-1} was observed at Wakawali with 90% confidence level. The decreasing, however, non-significant trend was observed at Karjat and Pali stations of North Konkan region. Increasing but non-significant trend was observed in the remaining stations. The number of annual rainy days increased from North to South part of the region. Similar trend was reported by Golekar *et al*. (2016). Mandal *et al*. (2013) reported that rainfall amount showed increasing trend and has positive correlation with rainy days in Sundarban region.

Seasonal variation and trends of rainfall and rainy days

Spatial variation and trend statistics of seasonal rainfall during different season is presented in Table 3. Results revealed that the amount of precipitation received during the *kharif* season at all stations was more than 90% of precipitation and the rest was received during *rabi* and summer seasons. Average rainfall during *kharif* season was in the range of 2247.7 to 3893.5 mm. Rainfall during *kharif* season exhibited a significant increasing trend at Suksale, Bhatsanagar, Karak and Mulde ranging between 23.36 mm yr^{-1} and 35.85 mm yr^{-1} whereas at Karjat and Dapoli there was a non-significant decreasing trend of *kharif* rainfall. Intensive water conservation practices are to be implemented at Karjat and Dapoli during rainy season to mitigate water scarcity during summer season. A non-significant increasing trend was observed at remaining locations.

Mean rainfall in the region during *rabi* season varied between 12.3 mm and 98.3 mm. Amount of rainfall during rabi season increased towards south part of the Konkan region, but this rainfall was very erratic in nature as indicated by the coefficient of variation. Significant increasing rainfall trend at 1.16 mm yr^{-1} was observed at Vengurla with 95 per cent confidence level whereas significant decreasing trend of 1.51 mm yr^{-1} was observed at Harnai at same confidence level. Out of ten remaining stations, five showed non-significant increasing trend and the rest showed non-significant decreasing trend of rainfall during rabi season. Rainfall during *rabi* season was reducing at Karjat, Harnai, Dapoli, Wakawali, Karak and Awalegaon which could lead to increasing moisture stress during the crop growth period and more supplemental irrigation water would be needed. Rainfall during *rabi* season showed increasing trend at Pali, Mulde and Vengurla which would contribute more effectively to meet the crop water requirement.

Rainfall during summer season varied from 3.2 mm at Bhatsanagar to 156.9 mm at Mulde. Rainfall exhibited significant decreasing trend at Wakawali station only. Rainfall during summer season at other stations was non-significant with increasing or decreasing trends.

Table 3. *Statistical parameters and trend statistics of seasonal rainfall in Konkan region*

Location	*Kharif* season					*Rabi* season					Summer season				
	Mean	CV	SD	Z	Q	Mean	CV	SD	Z	Q	Mean	CV	SD	Z	Q
Suksale	2505.3	20.4	511.8	2.4**	26.26	12.3	175.6	21.6	0.00	0.00	13.6	281.6	38.4	-0.50	0.00
Bhatsanagar	2558.5	20.9	534.1	2.16**	35.85	20.3	193.3	39.2	0.00	0.00	3.2	183.9	5.8	0.00	0.00
Karjat	3353.6	22.0	736.5	-0.74	-20.92	46.2	124.0	57.2	-1.14	-1.70	29.4	115.4	33.9	0.68	0.29
Pali	3403.8	19.3	655.7	0.78	12.86	22.7	159.0	36.0	0.63	0.01	37.7	195.8	73.7	0.98	0.00
Sudkoli	3086.5	23.7	729.2	0.25	7.20	10.8	193.0	20.9	0.00	0.00	15.9	319.2	50.8	0.00	0.00
Harnai	2247.7	25.1	563.3	1.09	11.88	46.1	107.5	49.6	-2.10**	-1.51	58.5	189.3	110.8	1.44	0.34
Dapoli	3684.0	20.5	755.4	-0.85	-9.62	55.5	121.3	67.4	-0.51	-0.21	58.2	173.9	101.2	0.35	0.01
Wakawali	3630.1	16.5	600.6	1.34	12.33	56.1	112.1	62.9	-0.27	-0.23	45.7	191.6	87.5	1.75*	0.33
Karak	3893.5	14.1	550.1	1.76*	23.36	83.4	78.6	65.5	-0.47	-0.54	119.1	131.3	156.4	0.35	0.20
Mulde	3081.9	16.4	504.1	1.71*	29.93	75.0	87.4	65.6	0.66	0.67	156.9	92.9	145.7	1.16	3.32
Awalegaon	3546.1	17.2	610.2	0.30	5.08	98.3	109.3	107.4	-1.11	-1.35	90.1	143.2	129.0	0.63	0.44
Vengurla	2872.9	21.9	629.6	0.90	14.38	34.3	165.7	56.8	2.07**	1.16	29.5	102.9	30.3	-0.23	-0.15

*Significance at 90% confidence level **Significance at 95% confidence level

Annual and seasonal variations of rainfall and rainy days indicated that very less amount of rainfall along with the rainy days occurred during the rabi and summer seasons, however, it is very important to assess the trend of rainfall during these seasons immediately after or before *kharif* season because this rainfall is very important as far as the strategies to cope up with the scarcity of water after monsoon season is concerned. Increasing rainfall during summer season may reduce moisture stress of mango and cashew crop, however it leads to increase in the incidence of pest and disease and affect the quality and yield of crop (Datta, 2013).

Variation of rainy days during different seasons with their statistical parameters and trends is presented in the Table 4. The data revealed that the rainfall occurs in more than 80 rainy days during *kharif* season, which is more than 90% of the annual rainy days. Remaining rainy days occur during *rabi* and summer seasons. Number of rainy days during *kharif* season was varied between 79.5 days at Suksale to 100.7 days at Karak. Rainy days during all seasons did not show any significant trend of variation in the region.

Monthly variation and trends of rainfall and rainy days

Monthly assessment of rainfall variation and its trend was also done for all locations under study and is represented in Tables 5 and 6, respectively. Average monthly rainfall during January, February, March and April was very meagre, which was less than 2 mm at most of the stations. Southern part of the Konkan region received more rainfall as compared to middle and northern parts of the region. Suksale and Bhatsanagar stations did not receive rainfall during January to April. Rainfall in the month of November was less than 10 mm in the north Konkan, whereas it was more than 20 mm in the southern part of the region. December month rainfall was less than 5 mm at most of the stations in the region. Rainfall during December to April was very scanty at all the study stations. This situation is good for the mango and cashew cultivation because the plants are on the efflorescence and fruiting stage during these months and no damage is expected due to rainfall during this period. Major rainfall *i.e.*, more than 85% amount is concentrated during June to October in the region. Rainfall in the month of June was less than 700 mm in the northern part of the region, while it was more than 800 mm in the southern part for most of the stations. July month received highest rainfall in the Konkan

Table 4. *Statistical parameters and trendstatistics of seasonal rainy days in Konkan region*

Location	*Kharif* season					*Rabi* season					Summer season				
	Mean	CV	SD	Z	Q	Mean	CV	SD	Z	Q	Mean	CV	SD	Z	Q
Suksale	79.5	11.6	9.2	0.00	0.00	0.7	172.8	1.3	0.0	0.00	0.4	204.4	0.9	0.00	0.00
Bhatsanagar	85.1	12.7	10.8	0.18	0.19	0.9	174.3	1.6	-0.90	0.00	1.1	159.3	1.8	0.73	0.00
Karjat	85.6	26.6	22.8	-0.09	-0.05	2.7	118.2	3.2	-1.18	-0.12	1.8	99.0	1.8	-0.10	0.00
Pali	91.7	9.1	8.4	-0.49	-0.11	1.5	125.7	1.9	0.37	0.00	1.3	149.4	1.9	1.15	0.00
Sudkoli	88.1	11.3	9.9	0.11	0.00	0.8	162.3	1.3	0.43	0.00	0.6	211.3	1.3	0.55	0.00
Harnai	77.6	13.6	10.5	0.53	0.13	2.4	89.2	2.2	-2.03	-0.08	2.3	148.1	3.4	1.16	0.00
Dapoli	92.0	11.8	10.9	0.58	0.14	3.1	75.4	2.3	1.11	0.04	3.6	112.8	4.1	0.72	0.00
Wakawali	95.8	8.5	8.2	1.37	0.22	3.3	80.8	2.7	0.00	0.00	2.4	139.5	3.4	1.19	0.00
Karak	100.7	7.1	7.2	1.60	0.22	4.6	75.6	3.5	0.05	0.00	5.5	89.6	4.9	0.36	0.00
Mulde	94.9	9.3	8.8	1.34	0.34	6.2	57.4	3.6	0.38	0.00	5.0	89.6	4.5	-0.07	0.00
Awalegaon	96.9	10.4	10.0	0.96	0.20	5.7	61.0	3.5	-1.98	-0.13	4.2	84.7	3.6	-0.14	0.00
Vengurla	86.2	10.9	9.4	1.19	0.21	5.1	56.4	2.9	0.69	0.00	4.2	107.2	4.5	0.34	0.00

region which was more than 1000 mm at eight out of twelve stations. At most of the stations, highest rainfall was observed in the month of July followed by August, June, September and October. The pre-monsoon rainfall is expected in many parts of the region during the month of May. The post-monsoon rainfall *i.e.*, during October and November months did not indicate any significant trend, however, very little but non-significant variation could be seen in both increasing and decreasing trends. Trend statistics revealed that rainfall during January to July did not evince any significant trend at any of the stations. Significant decreasing rainfall trend was observed at Dapoli (-10.53 mm yr^{-1}) in the month of August with a 90% confidence level. The results also indicated the significant increasing trend of rainfall during September month was exhibited at Suksale, Bhatsanagar, Wakawali, Karak, Mulde, Awalegaon and Vengurla at a rate between 5.87 to 14.54 mm yr^{-1}. This is a positive indication as far as longevity of water availability in the region is concerned. Rainfall in the month of October also did not exhibit any significant trend, whereas significant decreasing trend was observed in the month of November at Harnai. December month rainfall showed significant increasing trend at Vengurla at 90 per cent confidence level. This increasing rainfall would affect the flowering period of mango at Vengurla. Rainfall in the region was observed to shift mainly from June and August months to September at many locations. These trends are useful in the development of strategies for flood management, soil erosion control and water conservation and management.

Monthly variation and trend statistics of rainy days is presented in Table 7 and Table 8, respectively, which revealed that number of rainy days during December to April were less than 1 day at most of the stations. Rainfall and rainy days were found to have a positive correlation in the region. Significant rainy days were observed only during June to October months. Pre-monsoon rainfall in the month of May was received in the south part of the region which was increased significantly at Harnai. Number of rainy days in the month of June was varied from 6 days at Karjat to 20.5 days at Vengurla which did not showed any significant trend in the region. July month has highest monthly rainy days in the region which varied from 23 days at Harnai to 29 days at Karak. In the northern part of the Konkan region, rainy days showed significant increasing trend in the month of July at Bhatsanagar and Karjat. Rainy days in the month

Table 5. *Statistical parameters of monthly rainfall in Konkan region*

Months		Suksale	Bhatsanagar	Karjat	Pali	Sudkoli	Harnai	Dapoli	Wakawali	Karak	Mulde	Awalegaon	Vengurla
January	Mean	0.0	0.0	1.3	0.3	0.0	0.6	0.2	0.2	0.4	2.4	0.3	0.5
	SD	0.0	0.0	4.4	1.6	0.0	2.3	0.8	1.0	1.7	6.4	1.8	2.1
	CV	0.0	0.0	345.0	556.8	0.0	375.3	407.4	600.0	380.6	271.0	574.5	428.9
February	Mean	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.2	0.0	0.7	0.2	1.9
	SD	0.0	0.0	0.0	0.4	0.0	1.7	0.0	1.2	0.0	2.7	1.3	9.5
	CV	0.0	0.0	0.0	556.8	0.0	583.1	0.0	600.0	0.0	390.3	574.5	508.6
March	Mean	0.0	0.0	0.2	0.0	0.0	0.3	1.8	5.1	6.6	2.4	0.0	0.4
	SD	0.0	0.0	0.7	0.0	0.0	0.9	6.1	18.1	27.1	10.3	0.0	1.9
	CV	0.0	0.0	447.2	0.0	0.0	330.1	348.1	351.4	411.8	437.0	0.0	507.4
April	Mean	0.0	0.7	1.8	1.8	0.0	0.5	0.1	0.5	8.0	7.3	7.0	7.1
	SD	0.0	3.2	5.5	7.5	0.0	2.4	0.4	2.0	21.7	12.9	13.1	21.0
	CV	0.0	435.9	299.2	407.3	0.0	477.4	583.1	422.7	269.8	175.7	186.8	295.7
May	Mean	6.3	8.9	14.8	24.2	2.9	28.9	31.8	21.8	74.9	70.3	53.7	68.6
	SD	33.7	35.1	30.3	67.5	15.6	60.8	59.4	45.2	111.8	95.3	104.3	107.4
	CV	534.9	394.5	205.1	279.2	529.2	210.3	186.8	206.7	149.2	135.6	194.2	156.5
June	Mean	408.1	494.3	544.8	683.1	728.3	630.3	857.1	905.4	897.6	849.1	924.0	857.3
	SD	242.0	300.3	306.2	251.0	291.8	259.6	392.6	324.7	264.6	226.4	262.4	281.0
	CV	59.3	60.7	56.2	36.7	40.1	41.2	45.8	35.9	29.5	26.7	28.4	32.8
July	Mean	994.8	877.8	1248.9	1312.5	1127.7	753.7	1377.3	1346.9	1401.5	1096.1	1208.7	960.4
	SD	301.4	249.1	417.1	353.5	350.9	297.6	367.2	354.0	351.9	333.1	304.9	314.9
	CV	30.3	28.4	33.2	26.9	31.1	39.5	26.7	26.3	24.9	30.4	25.2	32.8
August	Mean	734.3	736.5	1045.6	910.6	779.4	161.1	912.3	899.7	1010.7	681.8	872.7	581.4
	SD	308.1	282.1	472.8	361.2	297.3	146.3	303.7	279.5	224.2	190.0	225.2	269.9
	CV	42.0	38.3	45.2	39.7	38.1	90.8	33.3	31.1	22.2	27.9	25.8	46.4
September	Mean	315.3	355.6	442.5	394.5	390.4	286.3	475.8	396.9	486.0	338.0	393.0	255.7
	SD	235.2	224.0	225.0	204.6	234.1	214.7	231.4	213.9	231.7	187.1	207.4	189.8
	CV	74.6	63.0	50.8	51.9	60.0	75.0	48.6	53.9	47.7	55.4	52.8	74.2
October	Mean	66.7	97.9	108.8	143.5	84.9	69.0	129.3	125.2	216.1	201.4	210.6	151.2
	SD	54.5	70.1	96.8	103.6	75.1	92.1	111.1	100.9	123.5	124.4	162.9	150.9
	CV	81.7	71.7	89.0	72.2	88.5	133.5	85.9	80.6	57.1	61.8	77.4	99.8
November	Mean	0.8	1.8	10.0	0.5	0.0	24.0	18.7	25.4	18.3	35.3	34.3	30.2
	SD	3.2	7.7	18.5	1.9	0.0	42.4	35.4	47.7	30.2	56.8	55.1	40.0
	CV	403.7	435.9	184.8	399.8	0.0	176.8	189.1	187.6	164.6	161.0	160.5	132.4
December	Mean	1.3	1.8	5.8	0.1	0.0	4.7	4.3	4.2	0.5	5.2	3.3	4.1
	SD	7.6	8.3	13.9	0.8	0.0	16.4	13.8	13.5	2.8	21.4	13.0	14.9
	CV	574.5	435.9	239.1	556.8	0.0	346.0	316.9	317.5	547.7	414.4	392.1	362.5

Table 6. *Trends of monthly rainfall in Konkan region*

Months		Suksale	Bhatsanagar	Karjat	Pali	Sudkoli	Harnai	Dapoli	Wakawali	Karak	Mulde	Awalegaon	Vengurla
January	Z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
February	Z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
March	Z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
April	Z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	-1.1	0.9	0.25
	Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	Z	0.00	0.00	0.43	0.60	0.00	1.81	0.85	0.06	-0.43	0.92	-0.03	1.73
	Q	0.00	0.00	0.00	0.00	0.00	0.10	0.02	0.00	-0.16	1.5	0.00	1.46
June	Z	0.75	-0.21	-0.55	0.00	-0.77	0.44	0.50	0.15	-0.29	-0.52	-0.54	-0.04
	Q	2.93	-2.86	-9.52	0.2	-6.78	1.49	4.63	0.95	-1.39	-4.86	-3.9	-1.00
July	Z	1.41	1.33	0.00	-0.37	-0.10	-0.09	-1.39	0.91	0.82	0.32	0.45	0.43
	Q	5.77	13.99	0.19	-2.5	-0.82	-0.3	-9.99	6.22	7.98	3.9	1.2	1.95
August	Z	0.82	1.40	-1.00	1.41	0.18	0.36	-1.87*	-1.21	-0.79	0.42	-1.22	-0.24
	Q	4.56	13.21	-23.80	10.5	1.52	0.59	-10.53	-4.46	-4.22	3.02	-5.8	-1.09
September	Z	1.91*	1.67*	0.91	1.56	0.89	0.83	0.18	2.6***	3.03***	2.51 **	2.4**	2.72***
	Q	5.87	13.51	3.72	6.97	6.17	2.45	1.08	9.2	14.54	12.78	8.2	11.42
October	Z	0.96	-0.32	-1.31	0.14	0.04	0.48	-0.07	1.26	0.14	0.00	0.14	0.79
	Q	1.12	-1.8	-3.44	0.33	0.07	0.25	-0.14	1.6	0.81	-0.1	0.3	1.27
November	Z	0.00	0.00	-1.61	0.00	0.00	-2.62***	0.00	-0.52	-1.04	1.41	-1.00	0.43
	Q	0.00	0.00	0.00	0.00	0.00	-0.21	0.00	0.00	0.00	0.5	-0.1	0.00
December	Z	0.00	0.00	0.00	0.00	0.00	0.83	0.00	0.00	0.00	0.00	0.00	1.89*
	Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*Significant at 90% confidence level, **Significant 95% confidence level, ***Significant at 99% confidence level

Table 7. *Statistical parameters of monthly rainy days in the Konkan region*

Months		Suksale	Bhatsanagar	Karjat	Pali	Sudkoli	Harnai	Dapoli	Wakawali	Karak	Mulde	Awalegaon	Vengurla
January	Mean	0.0	0.0	0.2	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1
	SD	0.0	0.0	0.5	0.2	0.0	0.3	0.2	0.2	0.3	0.3	0.3	0.3
	CV	0.0	0.0	287.7	556.8	0.0	326.3	406	600	393.2	270.3	574.5	399.7
February	Mean	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	SD	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0	0.2	0.2	0.9
	CV	0.0	0.0	0.0	0.0	0.0	583.1	0.0	600	0	489.9	574.5	485.8
March	Mean	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.2	0.0	0.0
	SD	0.0	0.0	0.2	0.0	0.0	0.2	0.4	0.4	1.1	0.8	0.0	0.2
	CV	0.0	0.0	491.9	0.0	0.0	406	296.3	268.3	348.6	399.8	0.0	575.7
April	Mean	0.0	0.1	0.2	0.1	0.0	0.1	0.1	0.1	0.5	0.5	0.5	0.3
	SD	0.0	0.2	0.4	0.2	0.0	0.4	0.2	0.2	0.9	0.7	0.8	0.7
	CV	0.0	435.9	161.2	387.1	0.0	429.3	406	418.2	190.5	157.3	155.7	227.4
May	Mean	0.2	0.3	0.9	0.7	0.2	1.6	2	1.6	3.5	3.4	2.4	2.8
	SD	0.7	1.0	1.3	1.4	1.1	2.9	3.2	2.5	4.1	3.6	3.7	3.8
	CV	399.8	317.6	144.9	203.2	548	179.5	159.3	162.2	119.7	106.9	152.6	134
June	Mean	13.1	14.3	15.5	16.7	16.7	15.6	19.2	18.8	20	19.2	20.1	20.5
	SD	4.0	4.6	37.2	3.8	4.2	3.8	4.0	4.4	4.1	4.3	3.8	3.1
	CV	30.6	32.1	619.8	22.7	25.5	24.4	20.6	23.2	20.3	22.5	19.1	15.1
July	Mean	25.7	25.5	27.2	27.8	28	23.8	28	28.6	29	28.2	28.2	26.1
	SD	3.2	3.4	10	2.5	2.6	3.5	2.4	2.1	2.0	2.9	2.4	2.4
	CV	12.4	13.3	43.5	9.1	9.2	14.5	8.7	7.2	7.0	10.1	8.6	9.3
August	Mean	24.7	25.4	26.5	26.6	26.4	22.1	27.1	28	28	26.6	27.4	23.5
	SD	3.4	3.1	23.4	2.9	3.6	4.4	3.3	2.6	2.8	3.2	3.0	3.1
	CV	13.7	12.1	292.3	10.9	13.7	19.8	12.1	9.3	9.9	11.9	11.1	13.1
September	Mean	13.1	15.8	16.6	16.2	14.4	13.3	15.4	16.6	18.4	16.3	17.2	13.2
	SD	4.6	5.1	31.3	5.3	5.6	5.8	5.4	5.0	4.8	5.2	5.8	5.5
	CV	34.8	32.3	1041.9	32.6	38.6	43.3	34.9	29.9	26	31.6	34	41.6
October	Mean	3.7	5.6	5.1	6.3	3.8	4.4	5.2	6.2	9.9	9.2	9.0	6.9
	SD	2.4	3.6	69.4	3.5	2.5	3.6	3.4	3.5	4.2	3.8	4.1	3.1
	CV	64	64.7	0.0	55.7	65.1	81.1	66	56.9	42.5	41	46.1	45.6
November	Mean	0.1	0.1	1.0	0.1	0.0	1.1	0.8	1.3	1.0	2.3	2.0	1.8
	SD	0.4	0.2	1.5	0.2	0.0	1.6	1.4	1.7	1.7	2.8	2.6	2.2
	CV	422.8	435.9	150.4	387.1	0.0	150.7	165	124.2	171.2	123.1	131.7	122.8
December	Mean	0.1	0.1	0.3	0.0	0.0	0.3	0.2	0.3	0.2	0.2	0.2	0.3
	SD	0.3	0.5	0.7	0.0	0.0	0.6	0.6	0.6	0.6	0.7	0.6	0.6
	CV	574.5	435.9	210.8	0.0	0.0	233.6	235.3	221.3	401.6	315.8	282.8	203.7

Table 8. *Trend statistic monthly rainy days in the Konkan region*

Months		Suksale	Bhatsanagar	Karjat	Pali	Sudkoli	Harnai	Dapoli	Wakawali	Karak	Mulde	Awalegaon	Vengurla
January	Z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
February	Z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
March	Z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
April	Z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.2	-1.13	0.3	0.00
	Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	Z	0.00	0.00	0.35	0.49	0.00	2.24**	-0.55	0.15	-0.19	0.08	-0.20	0.47
	Q	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.03	0.01	0.04	0.05
June	Z	0.53	0.11	0.05	-0.10	0.00	-0.06	1.02	1.12	-0.29	0.07	-0.02	-1.30
	Q	0.00	0.00	0.00	0.00	0.00	0.00	0.1	0.1	0.00	0.00	0.00	-0.1
July	Z	0.55	1.77*	2.32**	-0.54	0.53	0.46	1.40	0.62	1.28	0.15	0.89	0.07
	Q	0.01	0.20	0.40	0.00	0.01	0.01	0.1	0.00	0.00	0.00	0.00	0.00
August	Z	-1.41	0.29	-1.81*	-1.65*	-1.46	-0.04	-1.44	-1.88*	-1.46	-0.40	-2.37**	-1.34
	Q	-0.1	0.0	-0.6	-0.1	-0.1	0.0	-0.1	-0.1	-0.1	0.0	-0.1	-0.1
September	Z	0.42	0.32	0.73	0.50	0.96	1.40	1.23	1.44	2.57***	2.57***	2.25**	2.09**
	Q	0.00	0.1	0.3	0.0	0.1	0.2	0.1	0.1	0.2	0.4	0.2	0.2
October	Z	0.72	0.46	-0.82	0.72	0.82	0.06	0.37	1.54	1.25	-0.45	0.30	2.17**
	Q	0.00	0.10	-0.2	0.02	0.03	0.00	0.00	0.1	0.1	0.00	0.00	0.1
November	Z	0.00	0.00	-1.5	0.00	0.00	-2.8***	0.4	0.1	-0.5	2.0**	-0.9	0.00
	Q	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.1	0.00	0.00
December	Z	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.8	0.00	0.00
	Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*Significant at 90% confidence level, **Significant 95% confidence level, ***Significant at 99% confidence level

of August was more than twenty days in the region and a significant decreasing trend was observed at Karjat, Pali, Wakawali and Awalegaon. Average monthly rainy days in the month of September varied between 10 to 20 days in the region. Significant increasing trend of rainy days were observed in the southern part of the Konkan during September at Karak, Mulde, Awalegaon and Vengurla. The average monthly rainy days was less than 10 in October which showed increasing trend at Vengurla. Rainy day during November month was very scanty in the region which exhibited significant decreasing trend at Harnai, whereas it was increasing significantly at Mulde. Positive correlation was observed between the rainfall and rainy days during most of the months at almost all the stations in the Konkan region.

Dominance of variation in rainfall and rainy days during *kharif* season on the annual variation was observed more prominent at all study stations in the Konkan region. The assured and uniform distribution was observed in both parameters during *kharif* season at all stations. The annual rainfall and rainy days revealed significant increasing trend at Suksale, Bhatsananagar and Muldhe stations, whereas annual rainy days were significantly increasing at Wakawali. During *kharif* season rainfall increased significantly at Suksale, Bhatsanagar, Karak and Mulde. Rainfall during *rabi* and summer seasons was very erratic at all study station and significant increasing trend was observed at Vengurle during *rabi* season, while it was decreasing significantly at Harnai. Rainfall and rainy days in the month of September showed more impact of climate change as compared to other months. Significant change in rainy days was observed in the northern part of the region during July, whereas it varied in the southern part of the region during the months of September, October and November.

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