Spatio-Temporal Rainfall Trends in Konkan Region of Maharashtra State

V. P. Mandale[1], D. M. Mahale[1], S. B. Nandgude[1*], K. D. Gharde[1] and R. T. Thokal[2]
[1] Department of Soil and Water Conservation Engineering, College of Agricultural Engineering and Technology, Dapoli
[2] AICRP on Irrigation Water Management, Central Experimentation Centre, Wakavali
Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli - 415712 (MS).

Abstract

In recent past decades, climate change phenomenon has drawn wide attention across the world from all possible angles. A challenge posed by climate variability is ascertainment, identification and quantification of trends in rainfall and their implications on river flows. The present study was undertaken to identify the trends in rainfall considering past recorded data for eleven stations in five districts of Konkan region for 31 years (1981 to 2011) on monthly and annual basis. The trends in rainfall were estimated using Mann-Kendall and Sen's slope methods and results were compared. There were no trends observed for June, July, and August during the study period for the Konkan region estimated by both methods. Annual rainfall trends of study area estimated by Mann Kendal and Sen's slope methods were non significantly change. Comparatively, Mann Kendal's test found to be more accurate in estimating trends of rainfall over Sen's slope methods.

Keywords*:* Rainfall Trend, Mann-Kendall, Sen's slope, significant, non-significant.

Introduction

A number of studies were partially concentrated for analyzing the impact of climate change and variability on different components of the hydrological cycle. The magnitude and trend of warming of India during the last century over Indian continent is matching with the global condition. Drastic change in the hydrological dominant parameter such as precipitation is influencing the flow regimes substantially. Spatial and temporal pattern and variability of precipitation plays a vital role in modeling miscellaneous processes in hydrology, climatology, agriculture, environmental engineering, and forestry both at local and global levels (Anandhi *etal*. 2009 and Tabari *et al*. 2011).

Rainfed agriculture dominates the food grain production chain of Konkan region; any abrupt change in climate variables, particularly rainfall patterns poses serious threats to food and environmental security of the entire region. The region is less explored and very little is known, making the future climate change scenarios more uncertain for devising any conclusive mitigation and adaptation measures. The effects of climate change on precipitation occurrence, distribution, intensity, quality and quantity are resulting in noticeable changes in the hydrologic cycle. While the International Panel on Climate Change (IPCC) has projected an increase in global precipitation due to the effects of climate change, both increases and decreases in precipitation have been projected at the regional scale (IPCC 2007).

Global water resources are highly sensitive to both climate change and climate variation. Rainfall is the main input to the global hydrological cycle and an important indicator of water resources availability. It has shown significant change and variations over the years, both globally and regionally. In this region, the rains are highly variable in time, space, amount and duration, which is the most important limiting factor for biological and agricultural activities. Seasonal changes in rainfall pattern may alter the hydrological cycle and environmental processes, as well as, the vegetation and the entire ecosystem. Many studies have been conducted for the regional climate assessment of some countries of southwest Asia. The results of these studies have clearly

***Corresponding author :** nandgudesachin@gmail.com

shown that there is climate variability in these regions as a result of human interference on the ecosystems. From the year 1970 onwards, considerable literature concerning the trend detection techniques is available in environmental and hydrological field. Some of those studies are: Sen's nonparametric slope estimator (Sen, 1968), least squares linear regression for the detection of trends in time series of hydrological variables (Haan, 1977), the Spearman rank correlation test (Lettenmaier, 1988) and seasonal Mann–Kendall test [(Hirsch *et al*., 1982; Burn and Hag Elnur (2002), Xiong and Shenglian (2004)], Zhang *et al*. (2001)). Due to the perceptible increase in global average surface temperature, there is a drastic change in hydrologic parameters such as evaporation and precipitation resulting in cumulative impact on river flow regimes. In present study rainfall trends were identified by using Mann Kendal Test and Sen's slop estimator method on an Annual and Monthly basis for the Konkan region of Maharashtra State, India.

Material and Methods

Study area: The Konkan region is the coastal part of Maharashtra of India covering a total geographical area of 3.09 Mha. The Konkan region lies between $15^0$6' N to $20^0$22' N latitude and $72^0$39' E to $73^0$48' E longitudes, falls under heavy rainfall ranging from 2500 mm to 4500 mm. The region receives 46 % of total precipitation of the state on just 10 % of total geographical area of the state (NIDM, 2014).

Data used: Daily rainfall data of eleven rain-gauge stations viz. Jamsar, Savarkhand, Khapari, Karjat, Chowk, Varandoli, Dapoli, Karambavane, Mulde, Vengurla and Amboli stations of Konkan region were collected from Department of Agronomy, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli and Water Resources Department, Hydrology Project (Surface Water), Government of Maharashtra, Nasik were used for analysis of rainfall trends of Konkan region (Table 1).

Mann-Kendall Test (M-K) : The data values were evaluated as ordered time series. Each data value was compared with all subsequent data values. The initial value of the Mann-Kendall statistic, S, is assumed to be 0 (e.g. no trend), if a data value from a later time period is higher than a data value from an earlier time period, S is incremented by 1. On the other hand, if a data value from a later time period is lower than a data value estimated earlier, S is decremented by 1. The net

Table 1: Availability of data for study stations.

Station	Period (year)		Missing data	No. of years data available	Source
	From	To			
Jamsar	1986	2011	-	26	Unit of Hydrology Deptt., Nasik
Savarkhand	1991	2011	-	21	Unit of Hydrology Deptt., Nasik
Khapari	1992	2011	-	20	Unit of Hydrology Deptt., Nasik
Karjat	1989	2014	1989,1999, 2000, 2001, 2009	21	Dr. BSKKV, Dapoli
Chowk	1980	2011	2008	30	Unit of Hydrology Deptt., Nasik
Varandoli	1981	2011	-	30	Unit of Hydrology Deptt., Nasik
Dapoli	1981	2014	-	34	Dr. BSKKV, Dapoli
Karambavane	1991	2011	-	21	Unit of Hydrology Deptt., Nasik
Amboli	1981	2011	-	31	Unit of Hydrology Deptt., Nasik
Mulde	1991	2014	-	24	Dr. BSKKV, Dapoli
Vengurla	1981	2011	1983	30	Dr. BSKKV, Dapoli

result of all such increments and decrements yields the final value of S (Drapela and Drapelova 2011). Let 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:

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

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

If *n* is 9 or less, the absolute value of *S* is compared directly to the theoretical distribution of *S* derived by Mann and Kendall (Gilbert, 1987). A very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend (Bihrat and Mehmetcik, (2003), Choudhury et al. (2012), Kazimierz and Leszek, 2012).

If *n* is at least 10, the normal approximation test is used. For n ≥ 10, the statistic S was approximately normally distributed with the mean (Drapela and Drapelova 2011) and variance as follows.

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

Where,

q = Number of tied groups,

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

The standard test statistic Z computed as follows

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

The presence of a statistically significant trend was evaluated using the Z value. A positive/negative value of Z indicates an upward /downward trend. In the present study, confidence level of 99, 95 and 90 % signify the positive or negative trends determined by the test statistic. At the 99 % significance level, the null hypothesis of no trend is rejected if |Z| > 2.575; at the 95 % significance level, the null hypothesis of no trend is rejected if |Z| > 1.96; and at the 90 % significance level, the null hypothesis of no trend is rejected if |Z| > 1.645.

Sen´s slope estimator method: To estimate the true slope of an existing trend (as change per year) the Sen's nonparametric method is used. The Sen's method can be used in cases where the trend can be assumed to be linear. If a linear trend is present in a time series, then the true slope (change per unit time) was estimated by using a simple nonparametric procedure developed by Sen (1968). This means that linear model f (t) can be described as

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

Where,

Q_t = Slope

B = Constant.

To derive an estimate of the slope Q_t, the slopes of all data pairs were calculated

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

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

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

The procedure in MAKESENS computes the confidence interval at two different Confidence levels; α = 0.01 and α = 0.05, resulting in two different confidence intervals.

At first we compute

$$C\alpha = Z_{1-\alpha/2}\sqrt{(VAR\ (S)} \quad .....8$$

Where *VAR(S)* has been defined in equation (3.6) and Z1-α*/2* was obtained from the standard normal distribution. Next *M1 = (N - Cα)/2* and *M2 = (N + Cα)/2* were computed. The lower and upper limits of the confidence interval, *Qmin* and *Qmax*, where the $M1^{th}$ largest and the $(M2+1)^{th}$ largest of the N ordered slope estimates *Qt*. If *M1* is not a whole number the lower limit was interpolated. Correspondingly, if *M2* is not a whole number the upper limit was interpolated. To obtain an estimate of B in the equation (3.8) the *n* values of differences $xi - Q_t$ were calculated. The median of these values gives an estimate of B (Sirois 1998). The estimates for the constant B of lines of the 99 % and 95 % confidence intervals were calculated by a similar procedure.

Results and Discussion

The rainfall trends were identified by using Mann Kendal Test and Sen's slope estimator method on Annual and Monthly basis for selected stations for Konkan regions. Total 13 stations data of 25 to 30 years data were analysed to identify the rainfall trends based on availability of data.

Annual rainfall : The annual rainfall of Chowk (3197 ± 693 mm) with 22% variation showed a significant increasing trend of 26.91 mm/year. Average annual rainfall of Savarkhand (2547 ± 499 mm) with 20% variation evinced significant increasing trend of 22.88 mm/year. Average annual rainfall of Karanbavane (3893 ± 823 mm) with 21% variation and exhibited a significant increasing trend of 60.81 mm/year. Karjat and Varandoli showed non-significant decreasing trend of -15.1 mm/year and -7.33 mm/year, respectively. Jamsar, Khapari, Dapoli, Mulde, Vengurla and Amboli showednon-significant increasing trend of annual rainfall which is given in table 2. Maximum deviation (1457 mm) and variation (52%) was exhibited at Karjat. Minimum deviation as well as variation of annual rainfall was evinced in the southern part of the Konkan region. The District-wise deviation of annual rainfall was maximum in Raigad (945 mm) followed by Ratnagiri (828 mm), Sindhudurg (696 mm), Palghar (639 mm) and Thane (480) with coefficient of variation 31 %, 22 %, 17 %, 25 % and 19 %, respectively.

Monthly Rainfall Trends

Rainfall Trend for Month of June: The average rainfall in June month is given in table 3 for the study stations of Konkan region. The highest average rainfall was observed at Amboli station (1406.20 ± 488.07 mm) with 34.71 % variation and lowest at Khapari (415.51 ± 184.5 mm) with a coefficient of variation 44.38 %. A result also shows that, at Mulde observed rainfall was more

Table 2 : Trend of annual rainfall in the study area.

Name of Station	Mean (mm)	Min. (mm)	Max. (mm)	SD (mm)	CV (%)	Z	Q
Jamsar	2702	1703	5216	778	29	1.15	20.54
Savarkhand	2547	1641	3473	499	20	1.89*	22.88
Khapari	2478	1535	3564	480	19	0.69	12.14
Karjat	2801	1324	4709	1457	52	-0.23	-15.1
Chowk	3197	1814	4775	693	22	1.87*	26.91
Varandoli	3824	2627	5370	684	18	-0.58	-7.33
Dapoli	3635	2403	5291	832	23	0.62	11.6
Karambawane	3893	2731	5489	823	21	1.96**	60.81
Mulde	3330	2600	4314	454	14	0.72	13.21
Vengurla	2922	1224	4261	648	22	1.29	17.17
Amboli	6981	4873	8504	987	14	0.18	4.41

Note : *significant trend at the 90% confidence level; ** significant trend at the 95% confidence level; *** significant trend at the 99% confidence level.

Table 3 : Rainfall distribution at different stations during June, 2016 in the study area during

Name of Station	Mean (mm)	Min. (mm)	Max. (mm)	SD (mm)	CV (%)	Z	Q
Jamsar	436.67	22.60	1223.00	293.95	67.32	0.66	3.3
Savarkhand	429.41	49.60	1082.40	240.15	55.93	1.07	4.73
Khapari	415.86	103.50	845.00	184.57	44.38	0.45	6.11
Karjat	547.09	78.50	1141.50	290.29	53.06	-0.82	-12.98
Chowk	525.66	70.80	889.50	207.29	39.43	0.79	5.06
Varandoli	787.45	179.40	1505.80	334.06	42.42	-0.53	-4.4
Dapoli	859.06	186.60	2025.30	426.93	49.70	0.5	4.63
Karambawane	848.51	168.80	1781.60	392.84	46.30	1.24	17.02
Mulde	843.38	381.80	1353.80	244.09	28.94	-1.34	-9.24
Vengurla	875.47	387.00	1685.00	293.39	33.51	-0.04	-1
Amboli	1406.20	341.70	2464.00	488.07	34.71	0.02	0.32

Note : *significant trend at the 90% confidence level; ** significant trend at the 95% confidence level; *** significant trend at the 99% confidence level.

consistent as compared to all other stations and highest variation observed at Jamsar station. All stations receive more than 400 mm rainfall in June month. Average rainfall received in the month of June in the region was 725 mm with 309 mm standard deviation and 25 % coefficient of variation.

Ratnagiri district showed maximum deviation whereas, Palghar showed a maximum variation of rainfall in June. The Rainfall at Jamsar, Savarkhand, Khapari, Chowk, Dapoli, Karambawane and Amboli Stations showed non-significant increasing trend. Results also showed that non-significant decreasing trend at Karjat, Varandoli, Mulde and Vengurla. Middle and Southern part of Konkan region showed decreasing trend, whereas as northern part showed increasing trend of rainfall.

Rainfall Trend for Month of July: July month receives the highest amount of rainfall in the monsoon season in Konkan region. Average monthly rainfall in July was maximum at Amboli (2454 mm) followed by Karambawane (1409.25 mm) and Varandoli (1395.09 mm) whereas lowest rainfall was observed at Khapari (795.11 mm). Maximum monthly rainfall in July was observed at Karjat (2238.70 mm) and lowest at Vengurla station (274 mm). Maximum regional rainfall deviation in July month was observed at Jamsar (422.36 mm) and minimum rainfall deviation at Khapari with coefficient of variation 28.86% and 34.28%, respectively. All stations except Khapari (792 mm) received more than 900 mm rainfall in July. Southern part of Konkan region receives more rainfall in July as compared to northern part. Only Mulde station in the southern part of study region received more than 1100 mm average rainfall in July month. Coefficient of variation in monthly rainfall was observed highest at Jamsar station which is northern most station of the region. Average rainfall of Konkan region in the month of July was 1251 mm with standard deviation 379 mm and 31% coefficient of variation. The maximum deviation of rainfall in the month of July was maximum in Ratnagiri district followed by Sindhudurg, Raigad, Palghar and Thane, district with coefficient of variation 30.52%, 26.98%, 30.74%, 37.80% and 34.28%, respectively.

Average rainfall received in the study region during the July was 1251 mm with 379 mm standard deviation and 31% coefficient of variation. A non-significant decreasing trend was observed at Jamsar (-3.18 mm/year), Karjat (-9.72 mm/year), Varandoli (-4.59 mm/year) and Karambawane (-4.29 mm/year). From table 4 it is also revealed that, non-significant increasing trend was observed at Savarkhand, Khapari, Chowk, Dapoli, Mulde, Vengurla and Amboli stations. Northern and middle part of Konkan region exhibited decreasing, as

Table 4 : Rainfall distribution at different stations during July 2016 in the study area during.

Name of Station	Mean (mm)	Min. (mm)	Max. (mm)	SD (mm)	CV (%)	Z	Q
Jamsar	1040.08	355.90	2059.40	422.36	40.61	-0.42	-3.18
Savarkhand	905.21	243.60	1665.60	317.33	35.00	0.85	6.42
Khapari	795.11	352.88	1408.60	272.55	34.28	0.52	7.32
Karjat	1235.62	503.90	2238.70	413.96	33.50	-0.33	-9.72
Chowk	1161.45	446.50	1829.80	379.48	32.67	0.89	8.29
Varandoli	1395.09	782.60	2073.60	363.42	26.05	-0.63	-4.59
Dapoli	1283.90	419.00	2172.60	413.29	32.19	0.12	2.23
Karambawane	1409.25	761.40	2097.60	406.68	28.86	-0.15	-4.29
Mulde	1123.40	555.00	1580.80	278.60	24.80	0	0.14
Vengurla	959.12	274.00	1580.78	309.02	32.22	0.46	1.57
Amboli	2454.08	1406.10	3839.00	587.26	23.93	0.39	3.84

Note : *significant trend at the 90% confidence level; ** significant trend at the 95% confidence level; *** significant trend at the 99% confidence level.

Table 5 : Rainfall distribution at different stations during August 2016 in the study area.

Name of Station	Mean (mm)	Min. (mm)	Max. (mm)	SD (mm)	CV (%)	Z	Q
Jamsar	829.59	165.90	1686.60	400.01	48.22	1.23	14.49
Savarkhand	738.19	111.50	1428.40	299.51	40.58	1.39	10.16
Khapari	708.05	244.70	1275.84	277.35	39.17	0.39	6.8
Karjat	1047.12	130.20	2181.00	454.64	43.42	-0.94	-16.7
Chowk	962.25	194.70	2223.60	417.93	43.43	0.21	1.27
Varandoli	1047.39	399.20	1731.80	349.60	33.38	0.29	0.87
Dapoli	874.55	386.60	2051.00	354.13	40.49	-0.21	-1.52
Karambawane	950.51	420.30	1668.40	324.81	34.17	0.63	12.29
Mulde	698.78	233.70	1000.20	192.11	27.49	0.15	0.39
Vengurla	590.33	227.40	1599.30	269.69	45.68	-0.64	-3.68
Amboli	2033.61	728.20	4619.00	643.67	31.65	-0.53	-5

Note : *significant trend at the 90% confidence level; ** significant trend at the 95% confidence level; *** significant trend at the 99% confidence level.

well as, the increasing trend at some stations. Whereas, southern part only showed increasing trend in rainfall patter.

Rainfall Trend for Month of August: August month received ample amount of rainfall all over the Konkan region. All study stations received more than 600 mm average rainfall except Vengurla station in August. It is observed from Table 5 that, average monthly rainfall in August was maximum at Amboli (2033.61 ± 643.67 mm) with a 31.65% coefficient of variation and lowest at Vengurla station (590.33 ± 269.69 mm) with a 45.68% coefficient of variation. Amboli station exhibited maximum deviation as compared to all other stations and minimum deviation at the Mulde station with a coefficient of variation 31.65% and 27.49%, respectively. Mulde station received more uniform rainfall in the August as compared to remaining stations and Jamsar station adduces maximum variation among

the study stations. Average monthly rainfall in the month was more than 700 mm. Raigad district showed maximum deviation in rainfall during the month, followed by Sindhudurg, Palghar, Ratnagiri and Thane with coefficient of variation 40.07 %, 34.94 %, 44.4 %, 37.33 % and 39.17 %, respectively.

The Konkan region receives 952.76 mm average rainfall in the month of August with 362.13 mm standard deviation and 38.88 % coefficient of variation.

A non-significant decreasing trend was exhibited at Karjat (-16.7 mm/year), Dapoli (-1.52 mm/year), Vengurla (-3.68) and Amboli (-5 mm/year). The results also showed that non-significant increasing trend was observed at Jamsar (14.49 mm/year), Savarkhand (10.16 mm/year), Khapari (6.8 mm/year), Chowk (1.27 mm/year), Varandoli (0.87 mm/year), Karambawane (12.29 mm/year) and Mulde (00.39 mm/year). North Konkan didn't show a decreasing trend. However middle and southern part showed increasing, as well as, a decreasing trend of August month rainfall.

Rainfall Trend for Month of September: Monsoon rainfall decline in September month and received less rainfall as compared to June, July and August months at all stations. The maximum rainfall observed at Amboli station (740 ± 459.52 mm) with 62.1% coefficient of variation and lowest rainfall at Vengurla (261.16 ± 180.71 mm) with 69.19 % coefficient of variation. All study stations received less that 500 mm rainfall except Karambawane (505.92 mm) and Amboli (740 mm). Variation of rainfall from its mean was highest at Amboli and minimum at Khapari with 62.1 % and 35.26 % coefficient of variation in the month of September. Except Vengurla station, all stations conceded more than 300 mm in September. Highest deviation was observed in Sindhudurg district followed by Palghar, Raigad, Ratnagiri and Thane, whereas maximum variation was observed in Palghar district followed by Sindhudurg, Ratnagiri, Raigad and Thane district.

A significant increasing trend of September rainfall was observed at Karambawane (26.74 mm/year), Mulde (13.58 mm/year), Vengurla (9.64 mm/year) and Amboli (16.99 mm/year) (Table 6). The Non-significant increasing trend was exhibited at Jamsar, Savarkhand, Khapari, Karjat, Chowk, Varandoli and Dapoli. The month showed only increasing trend all over the Konkan region and it was significant in southern part only.

Rainfall Trend for Month of October: October month is the recession stage of monsoon rainfall and received lowest rainfall as compared to all monsoons season months in the Konkan region. Average rainfall in

Table 6 : Rainfall distribution at different stations during September 2016 in the study area

Name of Station	Mean (mm)	Min. (mm)	Max. (mm)	SD (mm)	CV (%)	Z	Q
Jamsar	327.13	24.6	949.4	272.94	83.44	1.5	5.41
Savarkhand	372.40	67.80	1069.26	268.26	72.03	1.14	5.05
Khapari	416.62	192.36	717.73	146.88	35.26	0.91	5.47
Karjat	434.2	27.9	869.2	215.75	49.69	0.94	4.38
Chowk	415.07	82.7	1122.6	215.46	51.91	0.57	1.96
Varandoli	447.46	114	962.1	220.62	49.31	0.22	1.18
Dapoli	433.96	43.2	919.4	245.71	56.62	1.66	7.49
Karambawane	505.92	99.4	928.6	242.59	47.95	2.87 ***	26.74
Mulde	339.03	54.5	733.1	187.67	55.36	2.51 **	13.58
Vengurla	261.16	32	731.4	180.71	69.19	2.5 **	9.64
Amboli	740	227	1752	459.52	62.1	2.36 **	16.99

Note : *significant trend at the 90% confidence level; ** significant trend at the 95% confidence level; *** significant trend at the 99% confidence level.

Table 7 : Rainfall distribution at different stations during October 2016 in the study area.

Name of Station	Mean (mm)	Min. (mm)	Max. (mm)	SD (mm)	CV (%)	Z	Q
Jamsar	67.17	0	204	57.46	85.55	0.46	0.51
Savarkhand	91.83	0	508.40	116.02	126.35	-0.32	-0.14
Khapari	101.32	0	235	67.19	66.32	0.26	0.56
Karjat	108.58	3	288.2	86.97	80.1	-0.91	-2.67
Chowk	122.23	0	318.3	95.69	78.28	0.1	0.18
Varandoli	116.74	0	389.2	95.48	81.79	-0.75	-1.48
Dapoli	125.73	0.5	472.8	110.52	87.9	0.09	0.18
Karambawane	217.93	0	822.8	185.53	85.13	0.21	1.61
Mulde	201.4	604.8	40	124.42	61.77	0	-0.09
Vengurla	146.75	685	16.6	150.34	102.44	1.27	1.98
Amboli	250.35	0	701	155.16	61.98	0.9	3.31

Note : *significant trend at the 90% confidence level; ** significant trend at the 95% confidence level; *** significant trend at the 99% confidence level.

October received maximum at Amboli (250.35 ± 155.16 mm) and minimum at Jamsar (67.17±57.46 mm) and many times for a considered study period October did not receive rainfall at every station. Table 4.6 reveals that highest deviation was observed at Karambawane (185.53 mm) and lowest at Jamsar (57.46 mm) with coefficient of variation 85.9 % and 85.55 % respectively. Palghar, Thane and Raigad district were showed less than 100 mm deviation in the month whereas Ratnagiri and Sindhudurg showed 148.03 mm and 143.31 mm deviation, respectively. Maximum variation of rainfall in the month was observed in Palghar district followed Ratnagir, Raigad, Sindhuudurg and Thane.

A non-significant increasing trend of October month rainfall was observed at Jamsar (0.51 mm/year), Khapari (0.56 mm/year), Chowk (0.18 mm/year), Dapoli (0.18 mm/year), Karambawane (1.61 mm/year), Vengurla (1.98 mm/year) and Amboli (3.31 mm/year). From Table 7 it is revealed that, non-significant trend was evinced at Savarkhand (-0.14 mm/year), Karjat (-2.67 mm/year), Varandoli (-1.48 mm/year) and Mulde (-0.09 mm/year).

Conclusion

The average annual rainfall distribution over the Konkan region was 3482 mm. Annual rainfall of Jamsar, Khapari, Dapoli, Mulde, Vengurla and Amboli showed non-significant increasing trend, whereas significant increasing trend was observed at Savarkhand, Chowk and Karambawane. Non-significant decreasing trend of annual rainfall was exhibited at Karjat and Varandoli. Non-significant increasing trend of annual rainfall was evinced in south part of the Konkan region.

The months of June and August rainfall didn't show any significant trend all over the region and non-significant increasing, as well as, a decreasing trend was exhibited in south and middle part of the Konkan region. Non significant increasing trend was observed in the north part of the region during June and August months. July and October month rainfall showed non-significant increasing, as well as, a decreasing trend in north and middle part of the Konkan region. Monthly rainfall of September month showed increasing trend all over the Konkan region and significant increasing trend was exhibited only south part of the region. The non-significant increasing trend observed for all over the Konkan region on annually and monthly basis.

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