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Climate Change

Spatio-temporal Trends of Rainfall and Rainy Days in the Marathwada Region of Maharashtra State

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Rainfall variability causes serious threats such as flood and drought which has severe impact on crop production, productivity, availability of water and biodiversity. Present study performed spatial and temporal trend analysis of annual and monthly (June to October) rainfall and rainy days in the Marathwada region of Maharashtra state. District-wise trend analysis of annual and monthly rainfall and rainy days were carried out by using non-parametric Mann-Kendall and Sen's slope test with 90 per cent, 95 per cent and 99 per cent confidence level. Results revealed that, annual rainfall showed non-significantly decreasing trend in most of the districts except Parbhani which was decreased significantly in the region. Rainfall during June month was reduced significantly in Jalna, Beed, Osmanabad, Latur and Parbhani district, whereas it was also dimming during August month in Parbhani and October month in Osmanabad district. Rainy days in the region did not evinced any significant change except during June month in the Nanded district which was decreasing significantly.

INTRODUCTION

Climate is the principal aspect of the physical environment offering economic development, Agriculture, Industry and all other factors of economic development of any region. It determines the distribution and performance of the cropping pattern of farmers. Climate change is acting as a trigger for changing rainfall pattern which can have significant impacts on hydrological cycle and regional crop calendar (Mirza and Hussain 2003; Abrol *et al*., 2004; David Chikodzi and Linda Yeukai Mapfaka, 2018). Rainfall is one of the decisive weather parameters for the detection of climate change (Sahu and Khare, 2015). Many researchers have studied annual and seasonal trends of rainfall in India at regional scale (Naidu *et al.,* 1999; Guhathakurta and Rajeevan, 2008; Kumar *et al*., 2010; Gosain *et al.,* 2011; Joshi and Pandey, 2011; Naveen Kumar *et al*. 2016). Annual and seasonal rainfall mitigates effect of monthly rainfall trend which affect crop production. Crop stage changes from month to month and productivity of crop and quality of produce affected with change in monthly rainfall (Katunzi *et al*. 2016; Momodou Badjie *et al*. 2019). Rainfall distribution within a month is indicated by number of rainy days which are more important for water resource planning and management point of view. Changing climate in India adversely affect the production and productivity of many crops (Datta, 2013). Most of the crops in the Marathwada region are rainfed cultivated and yield of crop depends on the availability of monthly rainfall and its distribution within a month. An acute information of annual as well as monthly rainfall and its trend is of prime importance because sustainability of rainfed agriculture and economic implications of rainfall dominated operation (Galkate *et al*., 1999). Recent trend of rainfall are more reliable for water management point of view because long period data also reduce the significance of trend. In the twenty first century a spatial and temporal analysis of rainfall in the region is essential to manage the crops water resources accordingly. Detection of rainfall and rainy days 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 hydrologic cycle of the region and can be helpful for the decision making in the water resource management. Climate change has worsened the situation over the last few years, which revealed that Maharashtra state particularly Marathwada region has recorded highest numbers of farmer's suicide in 2014. By keeping this in view, present study was undertaken for trend analysis of the annual and monthly rainfall and rainy days in Marathwada region.

Study area and data used

Marathwada is the drought prone region situated in the middle and south portion of the Maharashtra state falls within north latitude 17.35′ and 20.40′ and east longitude 74.40′ and 78.15′. The total area covered by Marathwada is 64,590 square kilometers which supports 1.87 crore population as per 2011 census. The entire region has rural setting and it comprises of eight districts *i.e.* Aurangabad, Beed, Jalna, Parbhani, Nanded, Hingoli, Osmanabad and Latur as shown in Figure 1. Nearly one third area of the Marathwada falls under the rainfall shadow where the rain is not only scanty but also erratic. Average annual rainfall in Marathwada region is 825.6mm with an average 45 rainy days which is mainly occurred during June to October. The western part of the region receives less rainfall as compared to eastern part and most of tehsils of the western Marathwada region is facing by droughts once in a decade.

Daily rainfall data of eight districts namely Aurangabad, Jalna, Beed, Osmanabad, Latur, Nanded, Parbhani and Hingoli was collected from Department of Agriculture, Government of Maharashtra for a

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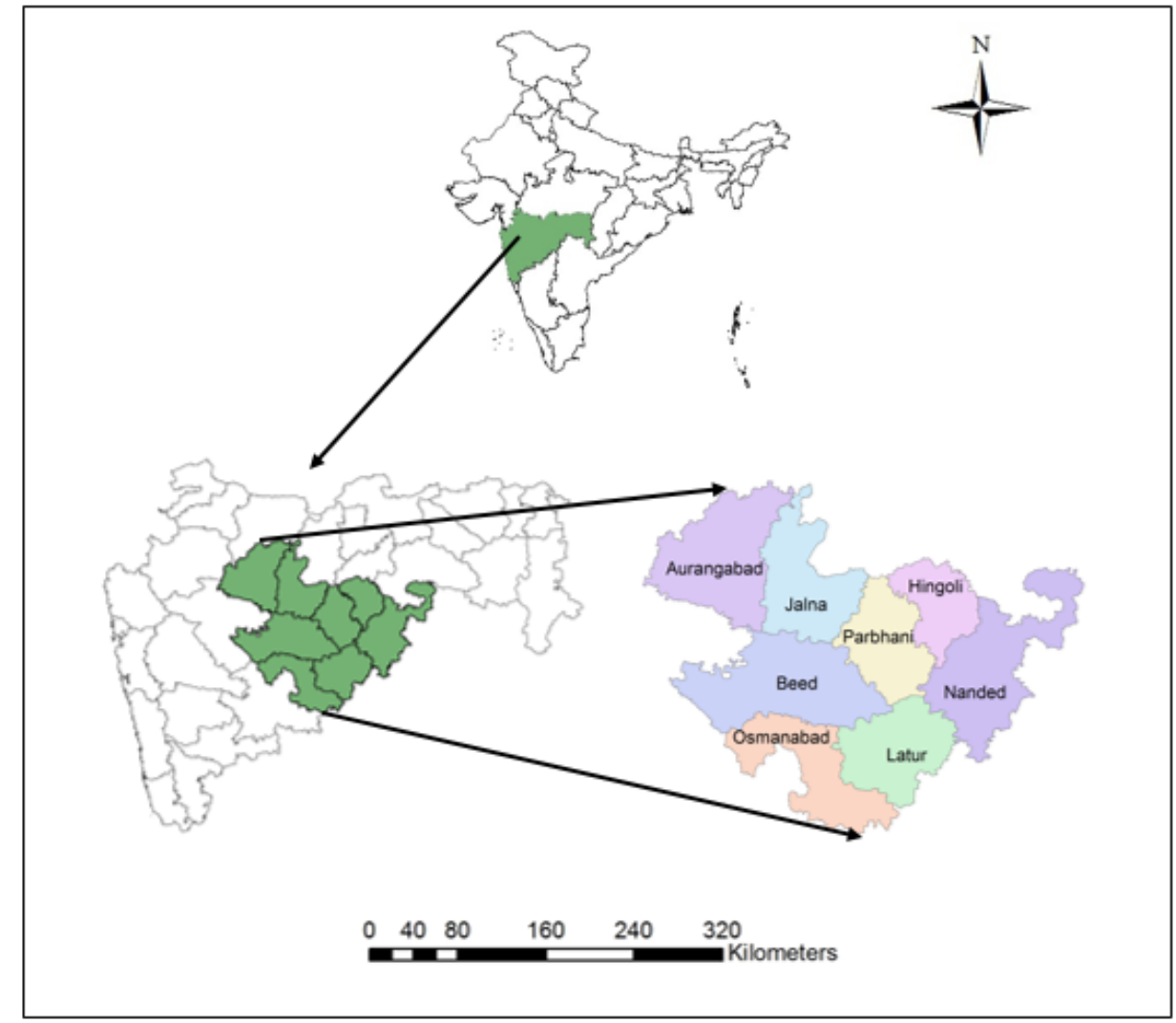

Figure 1 Location map of study area

period of 2001 to 2015. Rainfall received in a day ≥ 2.5 mm is considered as rainy days in the present study. Daily data was converted in to monthly and annual data which was used for further analysis. Rainfall in the region mostly received from south-west monsoon and concentrated only during a period of June to October and their after it is very meager which was not considered in the present study. Annual and monthly (June to October) trends of rainfall and rainy days were estimated as follows.

METHODOLOGY

Mann-Kendall test (M-K)

The Mann-Kendall trend test is useful to analyse data collected over time for consistently increasing or decreasing trends of variable (Kendall, 1995). It is a non-parametric test, which means it works for all distributions. 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 result of all such increments and decrements gives the final value of S (Drapela and Drapelova, 2011; Robaa and Zhian, 2013). For time series data with less than 10 data points the S test is used, and for time series data with 10 or more data points the normal approximation (Z) test is used as suggested by Gilbert (1987). Based on normalized test statistics (Z) value, the trend is said to be decreasing if Z is negative and increasing if the Z is positive. 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

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

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

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

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

Where,

q = Number of tied groups; and
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. In the present study, 90, 95 and 99per cent confidence levels were determined by the test statistic. At 90 per cent confidence level, the null hypothesis of no trend is rejected if |Z| $\geq$1.64; at 95 per cent confidence level, the null hypothesis of no trend is rejected if |Z| $\geq$ 1.96; and at 99 per cent confidence level, the null hypothesis of no trend is rejected if |Z| $\geq$2.57.The significance in trends were denoted as *** for 99 per cent confidence level, ** for 95 per cent confidence level and * for 90 per cent confidence level, respectively.

Sen´s slope estimator

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; Salmi *et al.*, 2002). This means that linear model f (t) can be described as

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

Where,
Q_t = Slope; and
B = Constant.

To derive an estimate of the slope Q_t the slopesof all data pairs was calculated

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

Where,

x_j =Magnitude of sample at j^{th} time;
x_k = 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 DISCUSSION

Average monthly rainfall contribution to annual total in the Marathwada

Average annual rainfall availability in the Marathwada region was mostly concentrated during June to September which was more than 90 per cent in all eight districts. Average monthly rainfall was maximum during August month in Aurangabad, Jalna, Beed, Osmanabad and Latur on the other hand July month received maximum rainfall in Nanded, Parbhani and Hingoli districts. October month received meager rainfall less than 10 per cent of the annual rainfall in all districts of the Marathwada region. Average rainfall received was more than 20 per cent of annual rainfall during each month of July, August and September.

	Contribution of monthly rainfall to annual total (%)					
Months	June	July	August	September	October	Total
Aurangabad	17.1	22.4	23.9	23.4	6.3	93.0
Jalna	15.9	24.0	25.3	21.5	7.7	94.5
Beed	15.7	20.5	23.0	23.7	9.3	92.4
Osmanabad	14.6	20.4	22.4	25.5	8.3	91.2
Latur	14.6	23.9	24.3	22.0	9.0	93.8
Nanded	16.2	28.1	27.3	18.3	5.9	95.8
Parbhani	14.8	26.8	26.2	19.3	7.9	95.1
Hingoli	16.1	27.7	25.7	19.0	7.3	95.9

Trend statistic of annual rainfall and rainy days in the Marathwada region

Average annual rainfall in the Marathwada region varied from 634.5 ± 136 mm year-1 in the Aurangabad district to 861.8 ± 256 mm $year^{-1}$ (Table 1). Amount of rainfall in the region was increased to west to east. Annual variability in the rainfall was lowest in the Aurangabad district whereas it was highest in the Parbhani district. Annual rainfall in the Parbhani district was reduced significantly by 28.5 mm $year^{-1}$ in the 21^{st} century, while remaining district did not evince any significant trend in the annual rainfall. Non-significant increasing trend of annual rainfall was observed in the Aurangabad and Beed district whereas non-significant decreasing trend was exhibited in the Jalna, Osmanabad, Latur, Nanded and Hingoli districts of the region.

Average annual rainy days in the Marathwada region varied between 50.7 ± 9 days $year^{-1}$ in Jalna district to 58.7 ± 10 days $year^{-1}$ in the Nanded district (Table 1). Temporal variation of annual rainy days was less than 25 per cent in almost all the district of the region. Annual rainy days did not change significantly in the almost all the district of the region. Rainfall in the Hingoli district was more than Nanded while rainy days was less which showed more rainfall intensity in the Hingoli district of the region.

Trend statistic of rainfall and rainy days in the month of June

Rainfall received during June month in the Marathwada region varied from 95.8 ± 51.5 mm in the Osmanabad district to 138.9 ± 96 mm in the Hingoli district (Table 2). Spatial variability of rainfall during June was less than 20 per cent, while temporal variation was more than 50 per cent in the region. Rainfall during June month exhibited significant dimming trend in Jalna (-8.9 mm $year^{-1}$), Beed (-6.5 mm $year^{-1}$), Osmanabad (-4.9 mm $year^{-1}$), Latur (-4.9 mm $year^{-1}$) and Parbhani (-8.8 mm $year^{-1}$) districts of the Marathwada region. Rainfall during June was also evinced non-significant decreasing trend in Aurangabad, Nanded and Hingoli districts. This change in the rainfall in the region aggravated a sowing time of *kharif* crops in the region. Reduced rainfall in the month of June also affects the water availability and needs to modify a crop calendar of the major crops in the region.

Table 1 Annual and Monthly rainfall trend in the Marathwada region of Maharashtra

District	Rainfall (mm)					Rainy days				
	Mean	SD	CV	Z	Q	Mean	SD	CV	Z	Q
Aurangabad	634.5	136.9	21.6	0.59	4.10	54.6	9.8	18	-0.69	0.00
Jalna	665.5	167.0	25.1	-1.13	-12.10	50.7	9.7	19.1	-0.40	-0.30
Beed	672.2	143.9	21.4	0.05	0.40	53.1	10.5	19.7	0.20	0.30
Osmanabad	656.9	167.1	25.4	-0.95	-8.60	55.1	11.4	20.7	-0.30	-0.10
Latur	774.6	173.7	22.4	-1.22	-12.70	57.4	11.3	19.7	-0.89	-0.80
Nanded	790.2	243.3	30.8	-1.22	-13.70	58.7	10.7	18.1	0.45	0.40
Parbhani	733.9	294.6	40.1	-2.03**	-28.50	52.9	11.2	21.3	-0.15	0.00
Hingoli	861.8	256.8	29.8	-0.32	-5.10	53.3	7.5	14.1	0.35	0.20

Table 2 Trend statistic of rainfall and rainy days in the month of June

District	Rainfall (mm)					Rainy days				
	Mean	SD	CV	Z	Q	Mean	SD	CV	Z	Q
Aurangabad	108.5	66.3	61.1	-1.13	-4.90	9.9	4.9	49.5	-1.19	-0.50
Jalna	105.9	67.9	64.1	-2.03**	-8.90	9.6	4.9	50.7	-0.90	-0.30
Beed	105.7	54.3	51.4	-1.76*	-6.50	10.5	3.6	34.4	-0.85	-0.30
Osmanabad	95.8	51.5	53.8	-2.03**	-4.90	9.8	4.1	41.9	-1.25	-0.30
Latur	113.3	64.1	56.5	-1.67*	-4.90	10.1	3.9	38.9	-1.24	-0.40
Nanded	127.9	62.4	48.8	-1.13	-4.90	10.9	3.3	29.8	-1.70*	-0.40
Parbhani	108.6	82.4	75.9	-2.12**	-8.80	9.4	3.1	33.4	-1.34	-0.30
Hingoli	138.9	96.3	69.3	-1.13	-5.10	9.7	3.9	39.7	-0.15	0.00

Table 3 Trend statistic of rainfall and rainy days in the month of July

District	Rainfall (mm)					Rainy days				
	Mean	SD	CV	Z	Q	Mean	SD	CV	Z	Q
Aurangabad	141.9	59.1	41.7	-0.05	-0.50	13.0	5.1	39.1	-0.40	-0.10
Jalna	159.6	97.6	61.1	-0.14	-1.70	11.9	5.4	45.1	0.00	0.00
Beed	138.1	105.6	76.4	0.50	5.30	10.0	6.0	60.4	0.80	0.30
Osmanabad	134.2	91.5	68.2	0.50	3.20	10.8	5.7	52.9	0.25	0.10
Latur	185.3	116.1	62.7	0.32	1.80	13.2	5.8	43.7	0.15	0.00
Nanded	222.3	169.7	76.3	-0.14	-0.90	15.1	5.9	38.8	0.00	0.00
Parbhani	197.0	168.6	85.6	-0.23	-2.00	12.6	5.5	43.4	0.00	0.00
Hingoli	238.8	176.2	73.8	-0.41	-2.50	13.5	5.2	38.2	0.30	0.00

Table 4 Trend statistic of rainfall and rainy days in the month of August

District	Rainfall (mm)					Rainy days				
	Mean	SD	CV	Z	Q	Mean	SD	CV	Z	Q
Aurangabad	151.7	62.5	41.2	-0.50	-2.10	12.1	2.7	22.0	-1.00	-0.30
Jalna	168.7	80.6	47.8	-0.23	-1.50	11.3	3.6	31.6	-0.50	-0.20
Beed	154.9	66.7	43.1	-0.23	-1.20	10.8	3.3	30.3	-0.10	0.00

Osmanabad	147.0	60.3	41.0	-0.41	-3.20	11.1	3.4	30.6	-0.75	-0.20
Latur	188.3	68.5	36.4	-1.22	-6.50	13.3	3.9	29.7	-0.10	0.00
Nanded	216.1	77.7	36.0	-1.49	-7.60	14.5	4.5	30.8	0.00	0.00
Parbhani	192.5	110.2	57.3	-1.85*	-12.80	12.7	4.5	35.4	0.00	0.00
Hingoli	221.5	113.9	51.4	0.00	-0.20	13.2	2.8	21.1	-0.61	-0.10

Table 5 Trend statistic of rainfall and rainy days in the month of September

District	Rainfall (mm)					Rainy days				
	Mean	SD	CV	Z	Q	Mean	SD	CV	Z	Q
Aurangabad	148.3	66.7	45.0	0.68	2.40	11.5	3.4	30.0	-0.15	0.00
Jalna	143.3	50.2	35.0	0.41	1.50	10.6	3.3	31.0	-0.30	0.00
Beed	159.6	80.3	50.3	0.14	0.60	12.0	4.8	39.7	-0.20	0.00
Osmanabad	167.7	79.9	47.6	0.05	0.60	12.7	4.3	34.1	-0.15	0.00
Latur	170.2	88.0	51.7	0.23	1.50	10.9	3.7	33.6	0.10	0.00
Nanded	144.3	55.7	38.6	0.41	2.10	10.9	3.3	30.5	0.96	0.10
Parbhani	141.6	69.9	49.4	0.95	2.70	10.9	3.8	34.8	0.40	0.10
Hingoli	164.0	37.8	23.0	0.59	3.30	10.8	2.3	21.6	0.45	0.00

Table 6 Trend statistic of rainfall and rainy days in the month of October

District	Rainfall (mm)					Rainy days				
	Mean	SD	CV	Z	Q	Mean	SD	CV	Z	Q
Aurangabad	39.8	25.4	63.8	0.14	0.50	3.6	2.3	63.7	-0.25	0.00
Jalna	51.4	46.5	90.5	-1.40	-2.10	3.6	2.4	66.2	-0.75	-0.10
Beed	62.7	45.6	72.8	-0.77	-2.40	4.9	3.0	61.0	-0.60	-0.10
Osmanabad	54.6	29.0	53.2	-1.76*	-2.40	5.0	2.5	50.1	0.00	0.00
Latur	69.5	57.3	82.4	-0.23	-0.20	5.1	2.9	57.5	-0.10	0.00
Nanded	46.6	46.8	100.3	-0.05	-0.40	3.9	3.2	80.1	-0.45	-0.10
Parbhani	58.1	83.1	142.9	-0.14	-0.40	3.9	3.1	79.3	0.00	0.00
Hingoli	63.2	77.3	122.2	-1.22	-2.10	2.9	2.2	75.6	-1.11	-0.20

Average rainy days in the month of June were lowest 9.4 days in the Parbhani district while it was highest 10.9 days in the Nanded district (Table 2). Number of rainy days in the month of June was decreased significantly in the Nanded (-0.4 days year^{-1}) whereas remaining district exhibited non-significant decreasing trend.

Trend statistic of rainfall and rainy days in the month of July

Assured rainfall was received in the region during July month which was varied between 135.2 ± 91 mm in Osmanabad to 238.8 ± 176 mm in the Hingoli district (Table 3). Nanded, Parbhani and Hingoli districts of Marathwada region received highest rainfall in the month of July. Results indicated that July month rainfall did not exhibit any significant trend in the region. July month rainfall revealed non-significant increasing trend in Beed, Osmanabad and Latur, whereas non-significant decreasing trend was observed in Aurangabad, Jalna, Nanded, Parbhani and Hingoli. This increase in rainfall in the region would improve the water availability which helps to reduce water scarcity during succeeding period.

Number of rainy days in the month of July was varied between 10 day in the Beed to 15.1 days in the Nanded district. Number of rainy days during July month in the region plays an important role in the crop sustainability and food production chain of the region, as most of the cultivated crop are in development stage which is sensitive to water availability, as most of area is rainfed.

Trend statistic of rainfall and rainy days in the month of August

Major part of the rainfall in the month of August is used as evapotranspiration of crops in the Marathwada region of the state. August month rainfall in the region was more than 150 mm except Osmanabad which was ranges from 147 ± 60.3 mm in Osmanabad to 221.5 ± 113 mm in Hingoli district (Table 4). Aurangabad, Jalna, Beed, Osmanabad and Latur received maximum rainfall during August month. Impact of climatic variability on the August month rainfall was not significant in the region except in Parbhani district which was reduced significantly by -12.8 mm year^{-1}. Monthly rainfall in the almost all

remaining districts are also showed non-significant deceasing trend in the region which is the alarming situation for the upcoming future.

Number of rainy days in the month of August was ranges between 10.8 days in the Beed district to 14.5 days in the Nanded district. It was also decreasing non-significantly in the most of the district except Nanded and Parbhai. Spatio-temporal variability of rainy days in the region during August month was less than that of rainfall at all the study stations.

Trend statistic of rainfall and rainy days in the month of September

Average rainfall (about 20 %) was received during September in the 21st century. Rainfall in the month of September was also more than 140 mm in the region, which varied from 141.6 ± 69 mm in Parbhani district to 170.2 ± 88 mm in Latur district (Table 5). Temporal variation in the September month rainfall and rainy days were less than 50 per cent and 40 per cent, respectively in the region. Trend statistic indicated that rainfall in the month of September was increased non-significantly in all the districts and significant change was not observed in the region. This increasing nature of rainfall would help to increase the availability of the water in the region during September month.

September month has more than 10 rainy days in the region which was varied from 10.6 ±3.3 days in Jalna to 12.7±4.3 days in the Osmanabad district (Table 5). Rainy days in the month of September was not varied significantly in the region.

Trend statistic of rainfall and rainy days in the month of October

Rainfall in the month of October recede in the region which reflect in the number of rainy days which was lowest 2.9 days in Hingoli whereas it was highest 5.0 days in Osmanabad. October month rainfall was more than 50 mm in the Jalna, Beed, Osmanabad, Latur, Parbhani and Hingoli, whereas it was less than 50 mm in Aurangabad and Nanded districts of the region. Rainfall in the month of October useful for the sowing and initial development stage of the many *rabi* crops, which has lack of irrigation facility such as red gram, sorghum etc. Impact of climatic variability on the October month rainfall was observed only in the Osmanabad district, which was decreased significantly, while non-significant dimming trend was evinced in the remaining districts except Aurangabad.

Number of rainy days in the month of October was less than 5 in most of the district but its usefulness is very high its variation was more than 50 per cent in the region. Rainy days was not changed significant in any of the district during October month.

CONCLUSION

In this study an attempt has been made to identify impact of climate change on the annual and monthly rainfall and rainy days in the eight district of the Marathwada region during 2001 to 2015 period. Trend analysis was carried out using Mann-Kendall and Sen's slope test method. Trend statistic indicated that annual rainfall in Parbhani district was increasing significantly while remaining district did not exhibit any significant trend. Rainfall in the month of June was dimming significantly in most of the districts except Aurangabad, Nanded and Hingoli districts. Monthly rainfall in the Parbhani district was changed significantly during August month whereas it was significantly reduced during October month in Osmanabad district. Rainfall in the month of July and September was not vary significantly in any of the district in the region. Annual and as well as monthly rainy days did not show any significant change in any of the district except Nanded during June month.

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