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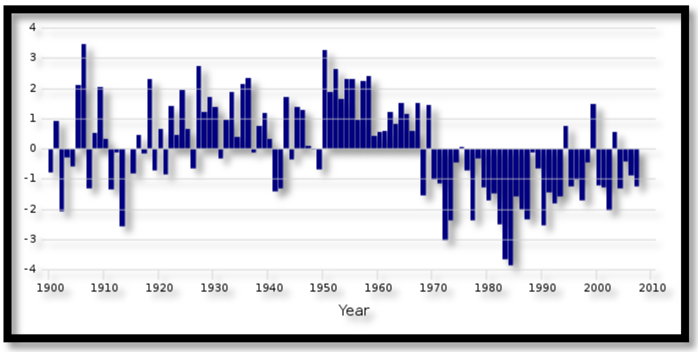
ORIGINAL ARTICLE

DETECTION OF TREND IN RAINFALL DATA: A CASE STUDY OF SANGLI DISTRICT



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ABSTRACT

In the present study, exploratory analysis of rainfall data is performed. This study aims to determine trends in winter, pre-monsoon, monsoon, post-monsoon seasons and annual at nine stations of Sangli district. The data used consists of season wise and station wise rainfall for the period 1981-2012. Non-parametric statistical tools such as *Sen's* estimator of slope and *Mann-Kendall* trend test was used to estimate the magnitude of trend. The post-monsoon time series of rainfall in Jath and Kavathe- Mahankal stations were observed to be statistically significant (p

< 0.10, p < 0.15). The downward trends are observed at the Atpadi and Tasgaon stations, but these trends were statistically insignificant.

Keywords: *Rainfall time series, Trend analysis, Mann-Kendall Test, Sen's estimate of slope.*

1. INTRODUCTION

Sangli district falls partly in Krishna basin and partly in Bhima basin. Consequently, it is divided into different drain systems. The whole district can be divided into three different parts on the basis of topography, climatology and rainfall viz.

1. Western hilly area of Shirala tahsil with heavy rainfall.
2. The basin area of Krishna, Warna & Yerala rivers, comprising of Walwa, tahsil & western part of Tasgaon and Miraj tahsils with medium rainfall.
3. Eastern drought prone area which comprises of eastern part of Miraj, and Tasgaon tahsils, north-eastern part of Khanapur tahsil and whole of Atpadi, Kavathe Mahankal and Jath tahsils.

The climate gets hotter and drier towards the east and humidity goes on increasing towards the west. The maximum temperature is 42º C while the minimum temperature is 14º C. The climate in the district is fairly tolerable throughout the year. The winter is pleasant from December to February. The summer season starts from mid February to May. June to September is the months of normal rainy season. July and August are the months of heavy rainfall. The average rainfall of Sangli district is 400-450 mm per year.

The purpose of present study is to investigate the variations in the rainfall in different seasons of Sangli district by detecting the precipitation changes in the temporal and spatial structure for the period 1981 to 2012. The present paper consists of five sections. The first section introduces the paper and motives of the work. The second section deals with survey of literature with special reference to trends in rainfall data. The third section describes study area, methodology and statistical techniques used for analysis. The fourth section discusses results and its discussion while the fifth one outlines concluding remarks.

2. SURVEY OF LITERATURE

Climatic studies aim to identify and determine the climatic changes in various contexts. Here, we take brief review of some of the research studies conducted in the context of trend analysis of Indian monsoon rainfall data. Time-series of annual rainfall, number of rainy-days per year and monthly rainfall of 10 stations were analyzed by **Zende et al. (2014)** to assess climate variability in semi-arid region of Western Maharashtra. They have reported that results showed mixed trends of increasing and decreasing rainfall, which were statistically significant only for Koregaon and Palus stations by the Mann–Kendall test. Also, with the exception of Vita and Vaduj stations there was no statistically significant trend in the mean number of rainy-days per year. Increasing and decreasing monthly rainfall trends were found over large continuous areas in the study region. These trends were statistically significant mostly during the winter and spring seasons, suggesting a seasonal movement of rainfall concentration. Results also showed that there is no significant climate variability in the semi-arid environment of Western Maharashtra. **Kumar and Jain (2010b)** have conducted study to determine trends in annual and seasonal rainfall and rainy days over different river basins across India. Among 22 basins studied by them, 15 showed a decreasing trend in annual rainfall; only one basin showed a significant decreasing trend at 95% confidence level. Most of the basins have shown the same direction of trend in rainfall and rainy days at the annual and seasonal scale. Rainfall is subject to strong seasonality in tropical monsoonal climate. **Kumar et al. (2010a)** studied monthly, seasonal and annual trends of rainfall using monthly data series of 135 years (1871–2005) for 30 sub-divisions (sub-regions) in India. Half of the sub-divisions showed an increasing trend in annual rainfall, but for only three (Haryana, Punjab and Coastal Karnataka), this trend was statistically significant. Similarly, only one sub-division (Chhattisgarh) indicated a significant decreasing trend out of the 15 sub-divisions showing decreasing trend in annual rainfall. They have also reported that during June and July, the number of sub-divisions showing increasing rainfall is almost equal to those showing decreasing rainfall.

There are spatial and temporal variations in various attributes of the rainy season such as starting date, ending date, durability, etc. Numerous notions of rainy season exist in the real world and the literature, e.g. green season, growing season, wet season, monsoonal rainy season and wet period. **Krishnakumar et al. (2009)** have studied temporal variation in monthly, seasonal and annual rainfall over Kerala, during the period from 1871 to 2005. Their analysis revealed significant decrease in southwest monsoon rainfall while increase in post-monsoon season over the State of Kerala which is popularly known as the 'Gateway of summer monsoon'. **Ranade et al. (2008)** have studied a hydrological wet season by taking into consideration important parameters such as starting and ending dates and duration, seasonal rainfall/rainwater and surplus rainfall/rainwater potential. They have performed analysis for the 11 major and 36 minor rivers basins as well as the West Coast Drainage System and the whole country using highly quality-controlled monthly rainfall from well spread network of 316 rain-gauge stations from earliest available year up to 2006. They have observed declining tendency in the rainfall/rainwater and surplus rainfall over most of the minor basins. The state-wise analyses of rainfall have also been reported in the literature.

As it can be seen from the above survey, previous studies have been conducted either river basin wise or state-wise. None of the study deals with month-wise and/or meteorological region-wise analysis of Indian rainfall data. **Shesabhare and Kalange (2012)** have studied the trends in the time series of rainfall data for more than 100 years. They have reported the results of the trends monsoon month-wise as well as meteorological region-wise. As far as Indian economy is concerned, district is considered as smallest unit of the nation and accordingly policies are worked out. Thus, geographical location like district is playing a crucial role in the formulation of policy. This aspect along with others motivated us to undertake the study of rainfall with study area limited to Sangli district.

3. METHODOLOGY

3.1 MATERIAL AND METHODS

The data used for this study is secondary data. The data is obtained from the Indian Meteorological Department, Pune. The data include the records of daily rainfall recorded at nine meteorological stations in Sangli district. The rainfall records include observations spanning from 1981 to 2012 and cover a period over 32 years. For the said purpose we consider four series of season-wise data namely winter season (January and February), pre-monsoon season (March, April and May), Monsoon season (June, July, August and September), post-monsoon season (October and November) and fifth series as annual rainfall data for all stations. The period of time series is long enough to carry out statistical analysis. As many hydrological time series data are not normally distributed, non-parametric tests were preferred over parametric tests. We have adopted methodology used by

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previous studies such Abdul-Aziz et al. (2013), Jain and Kumar (2012), Shesabhare and Kalange (2013),etc.

3.2 STUDY AREA

This study is conducted considering nine stations of Sangli district as a study area. The mean rainfall values of all ten stations were considered to represent the rainfall of the Sangli district. We study the season-wise rainfall trend at nine stations of Sangli district.

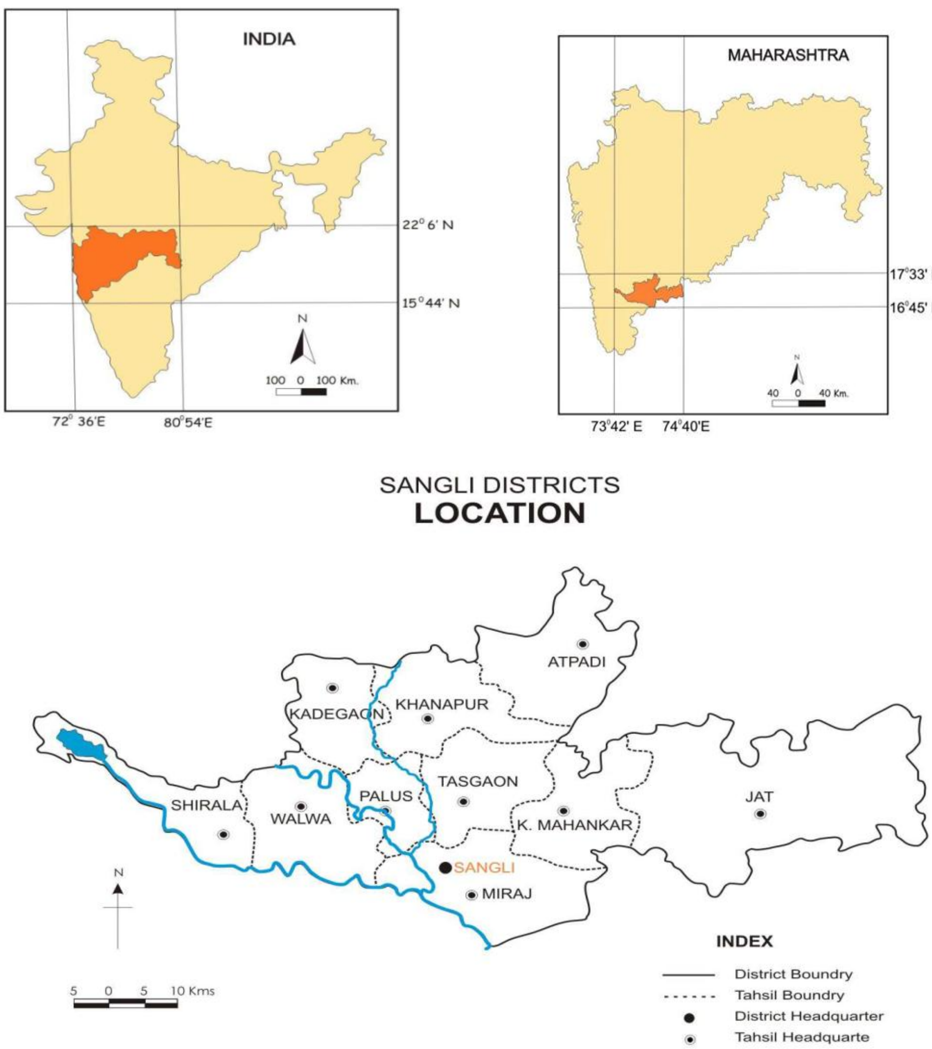

Figure 1: Location of Study Area

Table 1: Rainfall Gauging Stations

Sr. No.	Station	Elevation (masl*)	Mean Annual Rainfall (in mm)
1	Atpadi	552	419.61
2	Islampur	590	732.80
3	Jath	567	569.01
4	Kavathe Mahankal	627	477.48
5	Miraj	562	587.00
6	Palus	570	339.81
7	Sangli	549	517.66
8	Shirala	1040	1004.94
9	Tasgaon	585	598.77

*masl: Meters Above Sea Level

3.3 Sen's slope Estimator:

Previous studies have used different methodologies for trend detection. Trend analysis of a time series consists of the magnitude of trend and its statistical significance. In general, the magnitude of trend in a time series is determined either using parametric tests such as regression analysis or using non-parametric method such as Sen's estimator method. Both these methods assume a linear trend in the time series. Sen's slope estimator has been widely used for determining the magnitude of trend in hydro-meteorological time series. In this method, the slopes (T_k) of all data pairs are first calculated by

$$T_k = \frac{x_j - x_i}{j - i} \qquad for\ \ k = 1,2, \ldots\ldots, N$$

where, X_j and X_i are data values at time j and i (j > i)

The median of these N values of T_k is Sen's estimator of slope which is calculated as:

$$\beta = \begin{cases} T_{\frac{N+1}{2}} & N \text{ is odd} \\ \frac{1}{2}\left(T_{N/2} + T_{(N+1)/2}\right) & N \text{ is even} \end{cases}$$

A positive value of β indicates an upward (increasing) trend and a negative value indicates a downward (decreasing) trend in the time series.

3.4 Mann-Kendal Test:

The MK test checks the null hypothesis of no trend versus the alternative hypothesis of the existence of increasing or decreasing trend. i.e., H_0: There is no trend in the data values versus H_1: There exists trend in the data values.

The statistics (S) is defined as:

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

Where, N is the number of data points. Assuming $(X_j - X_i) = \theta$, the value of $Sgn\ (\theta)$ is computed as follows

$$sgn(\theta) = \begin{cases} 1 & if\ \theta > 0 \\ 0 & if\ \theta = 0 \\ -1 & if\ \theta < 0 \end{cases}$$

For large N, the test is conducted using normal distribution with mean and variance as follows:

$E(S) = 0$ and

$$Var(S) = \frac{N(N-1)(2N+5) - \sum_{k=1}^{n} t_k(t_k-1)(2t_k+5)}{18}$$

Where, n is the number of tied groups and t_k is the number of data points in the k^{th} tied group. The Standard Normal Variate (S.N.V.) is then computed as:

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

If the computed value is greater than critical value i.e., $|Z| > Z_{\alpha/2}$, the null hypothesis H_0 is rejected at α level of significance, where $0 < \alpha < 1$. The positive value of S indicates an 'upward trend', while a negative value indicates 'downward trend'

4. Results and Discussion

As for the identification of time series changing points, a preliminary graphical inspection is highly instructive and meaningful. All time series histograms show skewed nature of the distribution of data for all nine meteorological stations in Sangli district. Due to space constraint, histograms of only Atpadi and Shirala stations are illustrated in the **Figure 2**.

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Figure 2: Rainfall at Atpadi Station

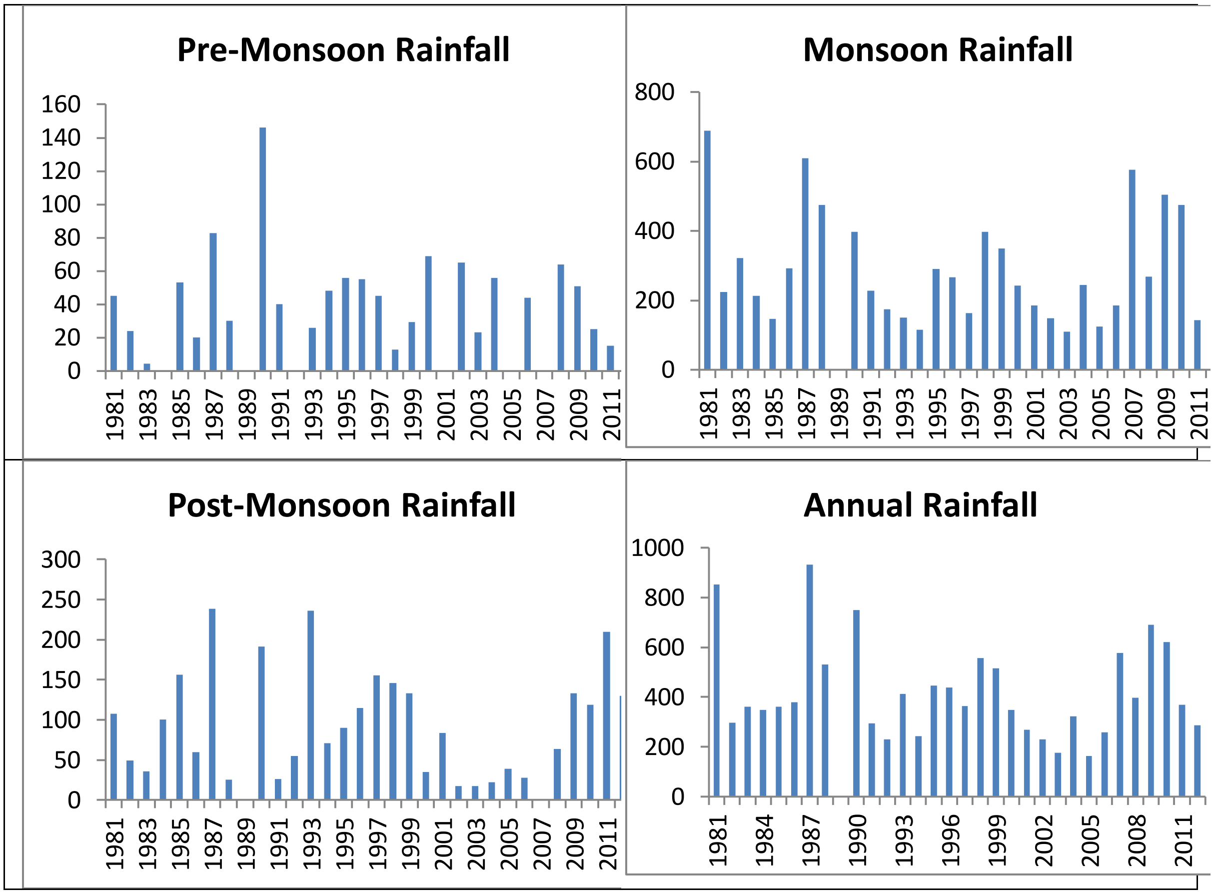
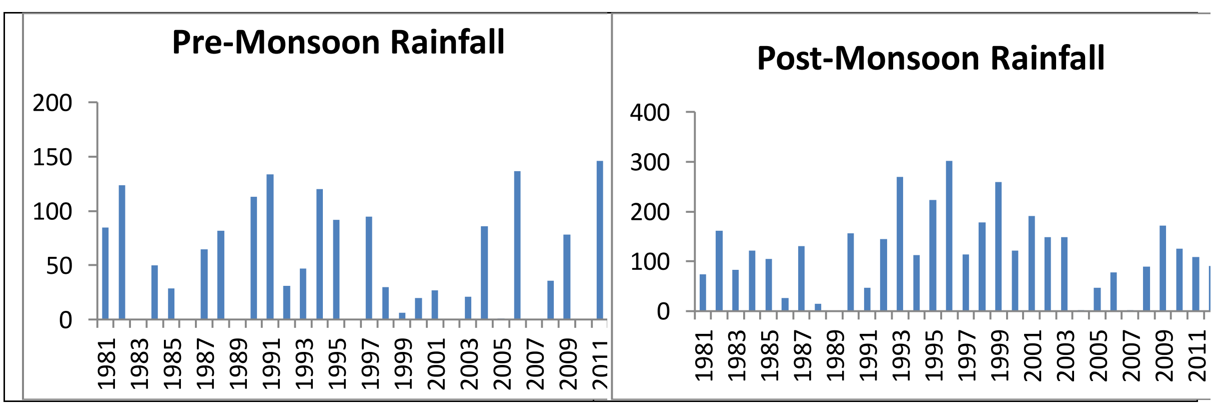


Figure 3: Rainfall at Shirala Station



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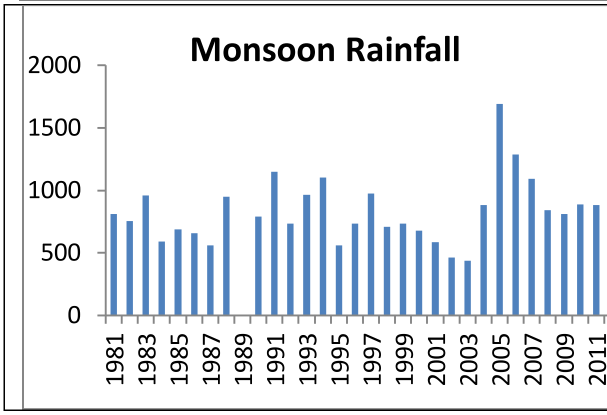

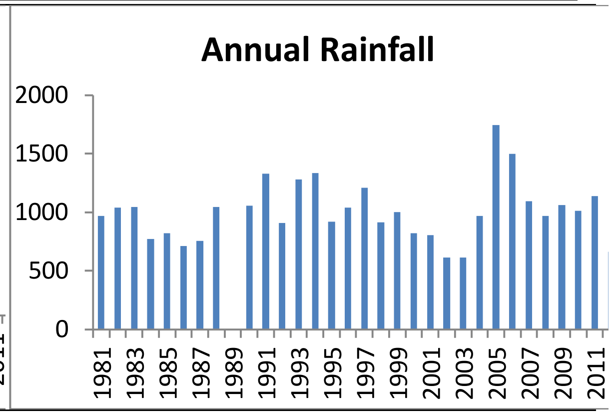

A trend is a significant change over time exhibited by a random variable, detectable by statistical parametric and non-parametric procedures. Onoz and Bayazit (2003) showed that the parametric *t* -test has less power than the non-parametric Mann–Kendall test when the probability distribution is skewed, but in practical applications, they can be used interchangeably, with identical results in most cases. With the aim of trend detection and cross verification, non-parametric statistical procedures are applied to the rainfall time series data. The rainfall time series are aggregated in the annual and also in seasonal time series (pre-monsoon, monsoon and post-monsoon) to further observe potential changes at the seasonal scale.

Table 2: Results of Mann-Kendal Test for Trend Detection

Rainfall Totals	Atpadi			Islampur			Jath		
	S-value	Z-value	P-value	S-value	Z-value	P-value	S-value	Z-value	P-value
Pre-monsoon	-19	-0.2945	0.7684	-89	-1.4338	0.1516	53	0.8507	0.3949
Monsoon	-49	-0.7784	0.4363	57	0.9081	0.3638	65	1.0379	0.2993
Post-monsoon	-16	-0.2432	0.8078	63	1.0056	0.3146	108	**1.7352***	**0.0827***
Annual	-26	-0.4054	0.6852	33	0.5189	0.6038	71	1.1352	0.2563
	Kavathe Mahankal			**Miraj**			**Shirala**		
	S-value	Z-value	P-value	S-value	Z-value	P-value	S-value	Z-value	P-value
Pre-monsoon	32	0.5037	0.6144	-48	-0.7656	0.4439	-43	-0.6871	0.492
Monsoon	87	1.3946	0.1631	68	1.0865	0.2773	33	0.519	0.6038
Post-monsoon	113	**1.8162***	**0.0693***	75	1.2	0.2301	11	0.1622	0.8712

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Annual	92	**1.4757#**	**0.14#**	80	1.2811	0.2002	45	0.7135	0.4755
	Palus			**Sangli**			**Tasgaon**		
	S-value	Z-value	P-value	S-value	Z-value	P-value	S-value	Z-value	P-value
Pre-monsoon	13	0.6055	0.5449	-98	**-1.6359**	**0.1019**	-97	**-1.5639#**	**0.1178#**
Monsoon	-9	-0.3959	0.6922	-82	-1.3145	0.1887	-13	-0.1946	0.8457
Post-monsoon	-16	-0.7423	0.4579	-5	-0.0675	0.9462	-10	-0.146	0.8839
Annual	-3	-0.099	0.9212	-84	-1.3469	0.178	-73	-1.1678	0.2429

* Statistically significant at 90% confidence level # statistically significant at 85% confidence level

Rainfall time series data were analyzed with Mann-Kendall test for all nine meteorological stations in Sangli district taking annual and also seasonal rainfall data. **Table 2** provides the calculations of Mann-Kendall Statistics and significant values. P-values are also provided. The downward trends in the annual as well as seasonal rainfall were exhibited for Atpadi, Sangli and Tasgaon stations, but these trends are statistically non-significant. For the Kavathe Mahankal and Jath stations, a weak upward trend is observed. The trends in the post-monsoon rainfall data for both of these stations, taking highest and second highest values, are observed statistically significant at 90% and 85 % confidence levels.

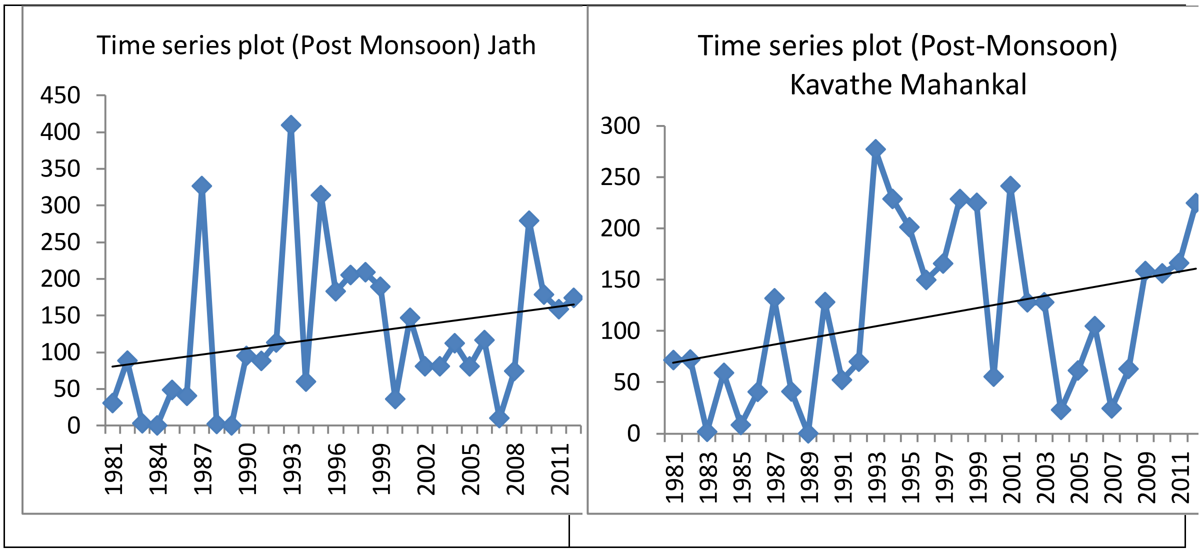
Table 3: Sen's slope estimate (mm/period)

Station	Sen's slope estimate (β)			
	Pre-monsoon	Monsoon	Post-monsoon	Annual
Atpadi	0.0000	-2.3650	-0.3804	-1.7458
Islampur	-1.0000	4.7735	1.7947	3.1149
Jath	0.4657	3.8478	**3.3100***	5.3612
Kavathe Mahankal	0.3935	4.4171	**3.1805***	6.0431
Miraj	-0.4255	3.6912	2.0450	4.7525
Palus	-0.4722	2.8722	0.1529	3.1554
Sangli	0.3333	-5.8545	-2.9000	-5.6000

Shirala	-0.6250	-6.8792	-6.8792	-7.0742
Tasgaon	-1.2156	-0.6352	-0.6588	-7.1511

* indicate statistically significant at 90% confidence level

Figure 4: Time plots of Seasonal Time series for Jath and Kavathe Mahankal Stations



As it can be seen from the **Figure 4**, an increasing trend in the post-monsoon rainfall data series for Jath and Kavathe Mahankal stations were observed.

Sen's slope estimator was also used to figure out the change per unit time of the trends observed in seasonal as well as annual time series. The computations of the Sen's slope estimator for all nine meteorological stations are presented in the **Table 3**, where a negative sign indicate downward slope and a positive sign an upward one. For seasonal time series data, statistically significant trend observed at Jath and Kavathe Mahankal stations.

5. Conclusions

The application of trend analysis revealed that upwards trend for some stations while downward for other stations. The continuous downward for Atpadi and Tasgaon stations while continuous upward trends for Kavathe Mahankal and

Jath stations were observed. The trends observed at all stations were statistically insignificant, except post-monsoon time series of Kavathe Mahankal and Jath stations. These results also indicated that for the analyzed time-period, there was no significant climate change in the study area. The results also suggest the need for further investigation on local environmental issues, which could be one of the major causes of climate change.

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