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Trend analysis of different climatic parameters in Dapoli region of Maharashtra

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Abstract
The present study examined the variability and trend of these climate variables for Dapoli (Maharashtra) over 37 years, from 1985 to 2021. While non-parametric methods like the Mann-Kendall and Sen's slope estimator test have been used to study trend analysis, statistical parameters have been used to analyse the variability of these climatic variables. The average annual minimum and maximum value of rainfall, maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, wind speed, sunshine hours, and pan-evaporation were found as 2330.7mm and 5421.4mm, 30.4 °C to 31.8 °C, 17 °C to 20.2 °C, 88.8% to 95.1%, 61.3% to75.4%, 3.8 km/hr to 5.4 km/hr, 6 hrs/day to 7.7hrs/day, and 1196.4 mm to 1780.8 mm, respectively. Annual trend of T_{min}, T_{max}, RH_{min}, and RH_{max} significantly increasing at 99.9%, 99.9%, 99.9%, and 95% levels of significance with a magnitude of 0.05 °C/year, 0.03 °C/year, 0.19%/year, and 0.07%/year, respectively. Wind speed and sunshine hours showed a decreasing trend at 95% and 99.9% levels of significance with the magnitude of -0.01 km/hr and -0.03 hr/day, respectively. There was no significant trend found for rainfall and pan-evaporation.

Keywords: Climate change, trend analysis, Mann-Kendall, Sen's slope

1. Introduction

Global climate change may fluctuate the long-term rainfall patterns, which might affect water supply and raise the risk of more frequent droughts and floods. Because of the unequal distribution of resources, India's problems are more severe than in other countries. According to IPCC, an increase of 1 degree Celsius might result in a 7% increase in severe rainfall. Global temperatures increased by 1 degree Celsius between 2011 and 2021 compared to the previous century. According to these reports, if the world's temperature rises by 1.5 degrees Celsius in the following decades, natural resources and humanity may be in grave danger compared to those below 1.5 degrees Celsius (IPCC 2022) [36].

According to the Fourth Assessment Report (FAR) of the Intergovernmental Panel on Climate Change (IPCC), climate change will significantly influence people and ecosystems in the future decades due to fluctuations in global average temperature and rainfall (IPCC, 2007) [37]. Agriculture and related industries are vulnerable to climate change. It will also have an impact on livelihoods and human well-being. As a result, the interaction between agricultural performance and climate, which has been an important topic of study for many decades, has gained traction as a result of increased awareness of the negative consequences of climate change on agriculture and livelihood. In the context of developing countries such as India, where agriculture continues to supply subsistence for more than two-thirds of the population, research on the nature and effect of climate change on agriculture and people's livelihoods is important (Ninan and Bedamatta 2012) [28].

Numerous studies conducted in the last few decades have documented the effects of climate variability and change as they are reflected in change in temperatures and rainfall. It is clear that the increase in global temperature is caused by greenhouse gas emissions and that turns in affect rainfall patterns. Recent studies of climate change and variability have been mainly focused on a basin scale, which provides more detailed information for better management and planning of local water resources (Getahun *et al*. 2021; Ramli *et al*., 2019; Elsanabary and Gan, 2015) [6, 31, 3].

The economy of India is mainly based on agriculture. Production capacity is pre-determined by exceptional weather conditions observed over a long period of time, assuming that other factors, such as soil, management practices, etc., do not change over many years. Favourable weather can give. India's vast geographic diversity, varied climate, soil types, and the topography create unique agricultural conditions, favouring some crops and deterring others

(Setiya and Nain 2021) [34].

Moreover, the accuracy of climate and hydrological studies depends on the quality of historical climate datasets (Getahun *et al* 2021; Javari, 2016; Ros *et al*., 2015) [6, 13, 32]. Unfortunately, many non-climate factors, such as changing weather and climate locations, measurement failure, data improper handling, and drastic climate conditions, can influence the accuracy of historical climate data, resulting in unrealistic trends, and introducing errors in further analysis (Getahun *et al* 2021; Rose *et al*., 2015) [6, 32]. Therefore, in order to perform precise studies of climate change and variability, it is essential to understand the factors that influence the quality of historical climate data. Studies on climate change and variability will be of better quality as a result of the analysis of trends in climatic parameters (Getahun *et al* 2021; Bisai *et al*., 2014; Jain *et al*., 2013) [6, 2, 12].

In present study trend analysis of climatic parameters were identified by using Mann Kendal Test and Sen's slop estimator method on an Annual and Seasonal basis for the Dapoli region of Maharashtra State, India. Various researchers prefer the Mann-Kendall test as one of the best methods for detection of trend in time series dataset. The Mann-Kendall test is used for analysis and the hypothesis test of hydrological variables defines statistical significance. Sens slope estimator is used describes the magnitude of increasing or decreasing trend.

2. Materials and Methods

2.1 Materials

The research work was carried out for the Dapoli tehsil of Ratnagiri district. The trend of six climatic variables viz., temperature (°C), rainfall (mm), wind (Km/hr), relative humidity (%) pan-evaporation (mm) and sunshine duration (hr) were analysed for the study area. Data daily related to these climatic variables were collected for 37 years (1985-2021) from the Department of Agronomy, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth Dapoli, Dist. Ratnagiri and India meteorological department (IMD) Pune. Geographical location of Dapoli station and availability and missing data period were presented in Table 1.

Table 1: Geographical location of Dapoli station and availability and missing data period

Geographical location		Availability of data			Source of data
		Climatic Parameters	Available	Missing	
Latitude	17° 75' N	Tmin/Tmax	1985-2021	-	Dr. BSKKV, Dapoli & IMD Pune.
		RHmin/RHmax	1985-2021	-	
Longitude	73°18' E	WS	1985-2021	-	
		SSH	1985-2021	-	
Mean sea level.	250	Pan-Evp	1985-2021	-	
		Rainfall	1985-2021	-	

2.1.1 Data analysis

MS-Excel sub-module was used for data analysis. MAKE SENSE excel template was used for trend detection and estimation of the magnitude (Salmi *et al.* 2002) [38].

2.2 Methodology

A. Descriptive Statistics

I. Mean (average)

The mean is a value arrived at by dividing the sum of observations by the total number of observations.

$$\overline{X} = \frac{\sum fx}{n} \quad (2.1)$$

Where,

f= the frequency; x= Mid-class value; n= Total number of observation

II. Standard Deviation

The standard deviation is the square root of the mean of the squared deviation of individual values from their mean.

$$S(\sigma) = \sqrt{\left[\frac{\sum x^2\left(\frac{\sum x^2}{n}\right)}{n-1}\right]} \quad (2.2)$$

Where,

$\sum x^2 \left(\frac{\sum x^2}{n}\right)$ = is called the sum of squares

III. Coefficient of variance

CV was used to investigate climatic parameters variability. The higher the calculated value of CV, the larger the variability, and vice versa.

$$C.V = \frac{\sigma}{Mean} \times 100 \quad (2.3)$$

Where,

CV is the coefficient of variation; **σ** is the standard deviation.

IV. Skewness

The coefficient of skewness is a measure of symmetry in the distribution. Positive skewness indicates a distribution with an asymmetric tail extending towards more positive values. Negative skewness indicates a distribution with an asymmetric tail extending toward more negative values.

$$S_k(b_1) = \frac{3(mean - median)}{S.D} \quad (2.4)$$

Where,

For symmetrical distribution, S_k =0; If the distribution is negatively skewed, then S_k is negative; If the distribution is positively skewed, then S_K is positive; The range of S_k is from -3 to +3.

V. Kurtosis

Kurtosis characterizes the relative peakedness or flatness of a distribution. Positive kurtosis indicates a relatively peaked distribution. Negative kurtosis indicates a relatively flat distribution.

$$b_2 = \frac{\frac{\sum f(x-\overline{x})^2}{n-1}}{\frac{\sum f(x-\overline{x})^4}{n-1}} \quad (2.5)$$

Distribution is called normal if b_2=3.When b_2 is more than 3, the distribution is said to be leptokurtic. If b_2 is less than 3, the distribution is said to be platykurtic.

B. Trend Analysis

Using a non-parametric technique called the Mann-Kendall (MK) Test, the trend of six meteorological variables has been examined (Mann, 1945 [22]; Kendall, 1975 [17]). Sen's slope estimator (Sen 1968 [33]) was employed to calculate the magnitude of the trend, with 90 percent, 95 percent, 99 percent, and 99.9 percent confidence levels.

I. Mann-Kendall Test

The Mann-Kendall test is best viewed as an exploratory analysis and is most appropriately used to identify stations where changes are significant magnitude. This test works well with skewed variables, is resistant to the impact of extremes, and can manage missing data. Instead of comparing the actual data values, the test evaluates the relative magnitudes of the sample data. This technique has often assessed the importance of trends in hydro-metrological time series. The alternative hypothesis (H_1), which asserts that there is a trend, is evaluated against the null hypothesis (H_0), which states that there is no trend (the data are objective and randomly arranged). Following the steps outlined below, the computed Z value is compared with the tabulated value at a certain level of significance to evaluate the existence of a trend that is either rising or decreasing.

The Mann-Kendall statistic (S) is calculated using

$$S = \sum_{i=1}^{n-1} \sum_{j=i=1}^{n} sign(x_j - x_i) \qquad (2.6)$$

An increasing trend is indicated by a very high positive value of S, while a decreasing trend is indicated by a very low negative value of S.

II. Sens Slope Estimator

Sen (1968) [33] gives the linear model to estimate the magnitude of the trend as follows:

$$f(t) = Q_t + B \qquad (2.7)$$

Where, Q_t = Slope; B = Constant.

1. Arrange the available data according to time series
2. To derive an estimate of the slope Q_t, the slopes of all data pairs were calculated

$$Q_t = \left(\frac{x_j - x_k}{j-k}\right), i = 1,2,3 \ldots N, j > k \qquad (2.8)$$

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

$$t = \begin{cases} \frac{Q_{N+1}}{2} \; If\ N\ is\ odd \\ \frac{1}{2}\left(\frac{Q_N}{2} + \frac{Q_{N+2}}{2}\right) If\ N\ is\ even \end{cases} \qquad (2.9)$$

Q_t is the magnitude of a trend, which is the median value of all slope values. Positive numbers indicate an upward trend, whereas negative values show a downward trend.

3. Results and Discussion

A. Descriptive statistics of climatic parameters

I. Minimum and Maximum Temperature

The nature and magnitude of climatic parameters at Dapoli are presented in Table 2. Annual mean value of minimum temperature (Tmin) was 19.0±0.8 ºC with CV of 4.2%. The minimum and maximum values of Tmin were 7.0 ℃ and 20.2 ℃, respectively. The seasonal mean value of Tmin during winter, pre-monsoon, southwest monsoon, and post-monsoon were 12.6±1.2 ℃, 19.5±0.9 ℃, 23.2±0.7 ℃ and 17.1±1.3 ℃ respectively. The CV of the parameters during winter, pre-monsoon, southwest and post-monsoon seasons was 9.6%, 4.6%, 2.8%, and 7.5%, respectively. Average minimum and maximum values of T min during winter, pre-monsoon, southwest and post-monsoon seasons were 10.4℃and 14.9 ℃, 17.7℃ and 21.2 ℃, 21.4 ℃ and 24 ℃, and 14.7 ℃ and 20.4 ℃, respectively.

Similarly, the annual mean value of maximum temperature (Tmax) was 31.0 ±0.4 ºC, and the CV was 1.4%. Seasonal mean values of maximum temperature during winter, pre-monsoon, southwest monsoon and post-monsoon were 31.3±0.8 ℃, 32.8±0.7 ℃, 28.8±0.5 ℃, and 32±0.6 ℃ respectively. The CV ranges from 1.70% during the southwest monsoon to 2.60% during winter. Average minimum and maximum values of Tmax during winter, pre-monsoon, southwest and post-monsoon seasons were 29.8 ℃ and 33.1 ℃, 31.3 ℃ and 34.2 ℃, 27.8 ℃ and 29.6 ℃, and 31℃ and 33.2 ℃, respectively.

II. Minimum and Maximum Relative humidity

Annual average RHmin and RHmax was 66.9±3.7% and 91.9±1.8%, respectively. The CV of RHmin and RHmax was 5.60% and 2.0%, respectively. Average minimum and maximum values of RHmin and RHmax were 61.3% and 75.4%, 88.8% and 95.1%, respectively.

Average RHmin and RHmax range from 50.4±8.7% (winter) to 85.7±3% (southwest monsoon) and 88.4±2.4% (pre-monsoon) to 94.1±1.7% (southwest monsoon) respectively. CV of RHmin and RHmax ranging from 3.50% (Southwest) to 17.30% (winter) and 1.80% (south-monsoon) to 2.70% (pre-monsoon), respectively. Average minimum and maximum values of RHmin during winter pre-monsoon, southwest monsoons and post-monsoon were 38.5 and 69.4%, 54.6 and 77.1%, 79.4 and 91% and 49.7 and 70.7%, respectively. Similarly, average minimum and maximum values of RHmax during winter pre-monsoon, southwest monsoons and post-monsoon were 87.3 and 96.4%, 83 and 92.8%, 90.6 and 96.9%, and 88.4 and 96.3% respectively.

III. Wind Speed

Table 2 indicated average annual wind speed in Dapoli region was 4.7±0.4 km/hr with CV of 9.0%. Average annual minimum and maximum values of wind speed in Dapoli region were 3.8 and 5.4 km/hr, respectively.

Maximum wind speed was during southwest monsoon (6.6±0.9 km/hr), and it was minimum during post-monsoon (2.6±0.4 km/hr). CV ranges from 10.0% during pre-monsoon to 16.30% during post-monsoon, indicating less variation in wind speed. Average seasonal minimum and maximum wind speed range from 0.9 km/hr (post-monsoon) to 4.3km/hr (South-west monsoon) and 3.2 km/hr (post-monsoon) to 8.7 km/hr (South-west monsoon), respectively.

IV. Sunshine Hours

The statistical analysis results for annual Sunshine hours (SSH) were tabulated in Table 2. Average yearly SSH in the Dapoli region was 6.6±0.4 hr/day with a CV of 6.50%. Minimum SSH in Dapoli region was 6 hr/day, and the maximum was 7.7 hr/day.

Average SSH in the Dapoli region was 6.6±0.4 hr/day (winter), 8.8±0.6 hr/day (pre-monsoon), 3.3±0.7 hr/day (southwest monsoon) and 7.6±0.5hr/day (post-monsoon). CV of SSH during winter pre-monsoon southwest monsoon and post-monsoon was 6.50%, 7.30%, 20.10% and 6.70%, respectively. CV showed a high value during southwest monsoon (20.10%), meaning the variation in SSH during southwest monsoon was more. The minimum and maximum values of SSH range from 2 hr/day (southwest monsoon) to 7.2 hr/day (pre-monsoon) and 4.5 hr/day (southwest monsoon) to 10.1 hr /day (pre-monsoon), respectively.

V. Pan-evaporation

Average annual Pan-Evp in Dapoli region was 1453.1±144.9 mm/year with the CV of 10.0%. Annual minimum and maximum values of Pan-Evp were 1196.4 mm/year and 1780.8 mm/year, respectively.

Seasonal Pan-Evp during winter pre-monsoon southwest monsoon and post-monsoon was 242.8±21.1, 407.6±37.3, 277.8±17.4 and 227.5±35 mm/year, respectively. CV of Pan-Evp was 8.70% (winter), 9.20% (pre-monsoon), 6.30% (southwest monsoon) and 15.0% (post-monsoon). The minimum and maximum values of Pan-Evp range from 167.8 (post-monsoon) to 349.8 mm/year (pre-monsoon) and 278.6 (winter) to 462.6 mm/year (pre-monsoon), respectively.

VI. Rainfall

The average annual rainfall in the region was 3691.7±874.1 mm/year, with a CV of 23.70%. Annual minimum and maximum rainfall values were 2330.7 mm/year and 5421.4 mm/year, respectively.

Seasonal rainfall in winter, pre-monsoon, southwest-monsoon and post-monsoon was 0.6±2.8, 40.6±67.3, 3507.9±813.4 and 142.5±112 mm/year, respectively. The highest CV was found in winter (448%) and pre-monsoon (165.60%), and post-monsoon season (78.60%), which means rainfall variability in these seasons is more. Due to rain's erratic nature, rainfall variation is more in this season. Average minimum and maximum rainfall in winter, pre-monsoon, southwest monsoon and post-monsoon season was 0 and 16.8 mm/year, 0 and 238.2 mm/year, 2126.7 and 5046.4 mm/year, 3.8 and 501.2 mm/year respectively.

Table 2: Descriptive Statistics of Weather parameters

Weather Parameters	Descriptive Statistics	Annual	Seasons			
			Winter (Jan-Feb)	Pre-Monsoon (March-May)	Southwest-Monsoon (Jun-Sept)	Post-Monsoon (Oct-Dec)
Tmin (°C)	Mean	19	12.6	19.5	23.2	17.1
	SD	0.8	1.2	0.9	0.7	1.3
	CV%	4.20	9.60	4.60	2.80	7.50
	Kurtosis	0	-0.8	-0.8	0.4	0.1
	Skewness	-0.6	0.1	-0.2	-0.9	0.2
	Minimum	17	10.4	17.7	21.4	14.7
	Maximum	20.2	14.9	21.2	24	20.4
Tmax (°C)	Mean	31	31.3	32.8	28.8	32
	SD	0.4	0.8	0.7	0.5	0.6
	CV%	1.40	2.60	2.00	1.70	1.80
	Kurtosis	-1.3	-0.8	-0.3	-0.8	-0.4
	Skewness	0.1	0.1	0	-0.1	0.4
	Minimum	30.4	29.8	31.3	27.8	31
	Maximum	31.8	33.1	34.2	29.6	33.2
RHmin (%)	Mean	66.9	50.4	61.4	85.7	58.2
	SD	3.7	8.7	5.3	3	5.7
	CV%	5.60	17.30	8.60	3.50	9.70
	Kurtosis	-0.6	-0.6	1.8	-0.6	-0.8
	Skewness	0.3	0.7	1.3	-0.2	0.5
	Minimum	61.3	38.5	54.6	79.4	49.7
	Maximum	75.4	69.4	77.1	91	70.7
RHmax (%)	Mean	91.9	92.5	88.4	94.1	92.2
	SD	1.8	2.4	2.4	1.7	2.2
	CV%	2.00	2.60	2.70	1.80	2.40
	Kurtosis	-1.1	-0.7	-0.3	-1.1	-1.1
	Skewness	0.1	-0.1	0	-0.3	0
	Minimum	88.8	87.3	83	90.6	88.4
	Maximum	95.1	96.4	92.8	96.9	96.3
Wind Speed (Km/hr)	Mean	4.7	3.3	5.4	6.6	2.6
	SD	0.4	0.5	0.5	0.9	0.4
	CV%	9.00	15.90	10.00	14.20	16.30
	Kurtosis	-0.7	6.8	4.6	-0.2	5.7
	Skewness	-0.6	-2.3	-1.5	0	-1.8
	Minimum	3.8	1.4	3.3	4.3	0.9
	Maximum	5.4	4	6.1	8.7	3.2
SSH (hr)	Mean	6.6	6.6	8.8	3.3	7.6
	SD	0.4	0.4	0.6	0.7	0.5

	CV%	6.50	6.50	7.30	20.10	6.70
	Kurtosis	-0.3	-0.3	-0.2	-0.7	-0.4
	Skewness	0.5	0.5	0	0.1	0.8
	Minimum	6	6	7.2	2	6.9
	Maximum	7.7	7.7	10.1	4.5	8.7
Pan-Evp (mm)	Mean	1453.1	242.8	407.6	277.8	227.5
	SD	144.9	21.1	37.3	17.4	35
	CV%	10.00	8.70	9.20	6.30	15.40
	Kurtosis	-0.1	-1.1	-1.4	-1.5	-1.2
	Skewness	0.5	0.2	-0.1	-0.2	0
	Minimum	1196.4	208.6	349.8	250.8	167.8
	Maximum	1780.8	278.6	462.6	300.4	284.8
Rainfall (mm)	Mean	3691.7	0.6	40.6	3507.9	142.5
	SD	874.1	2.8	67.3	813.4	112
	CV%	23.70	448.80	165.60	23.20	78.60
	Kurtosis	-0.8	31.9	2.3	-0.8	1.7
	Skewness	0.3	5.5	1.9	0.2	1.1
	Minimum	2330.7	0	0	2126.7	3.8
	Maximum	5421.4	16.8	238.2	5046.4	501.2

A. Trend analysis of climatic parameters
Trend analysis has been carried out using the non-parametric Mann-Kendall test for the annual and seasonal time series of seven climatic variables from 1985 to 2021. Sen's slope estimator was also used to assess the magnitude of the trend. Sens slope is measured in mm for rainfall and pan-evaporation, °C for maximum and minimum temperatures, km/hr for wind, % for relative humidity, and hrs for Sunshine hours. In contrast, Mann-Kendall statistics is a unit less quantity. A positive Sen's slope value indicates an upward trend, whereas a negative Sen's slope value indicates a downward trend. Trend statistics of climatic parameters on an annual and seasonal basis for the Dapoli region are tabulated in Table 3.

I. Annual trend
Annual trend statistics of climatic parameters for the Dapoli region are presented in Table 3. From Table 3 revealed a trend of T_{min}, T_{max}, RH_{min}, and RH_{max} significantly increasing at 99.9%, 99.9%, 99.9%, and 95% levels of significance with a magnitude of 0.05 °C/year, 0.03 °C/year, 0.19%/year, and 0.07%/year, respectively. Wind speed and sunshine hours showed a decreasing trend at 95% and 99.9% levels of significance with the magnitude of -0.01 km/hr and -0.03 hr/day, respectively. There was no significant trend found for rainfall and pan-evaporation.

II. Seasonal Trend
Seasonal trend statistics of climatic parameters for the Dapoli region are presented in Table 3. From Table 3, it was indicated that T_{min} and T_{max} are significantly increasing for all the seasons. For the winter season, T_{min} and T_{max} increased at a 99.9% and 95% significance level with a magnitude of 0.05 °C/ year and 0.03°C/ year, respectively. For pre-monsoon season, T_{min} and T_{max} increased at 99% and 99.9% significance levels, with a magnitude of 0.05 °C/year and 0.04 °C/year, respectively. For southwest monsoon, T_{min} and T_{max} have shown increasing trends at 99.9 and 99% significance levels with and magnitude of 0.07°C/year and 0.02°C/year, respectively. For post-monsoon season T_{min} and T_{max} were increased at 99.9% and 99% levels of significance with a magnitude of 0.07 °C/year and 0.02 °C/year, respectively.

Similarly, trend statistics of RH_{min} and RH_{max} are also presented in Table 3. For winter seasons, average RH_{min} exhibited a significantly increasing trend at 99.9% level of significance with a magnitude of 0.44%/year. In contrast, No significant trend was found for the RH_{max} for the winter season. For pre-monsoon season, no significant trend was found for RH_{min} and RH_{max}. RH_{min} and RH_{max} has shown an increasing trend in the southwest monsoon season at 99% and 95% significance levels, and the magnitude of trend was 0.14%/year and 0.08%/year, respectively. Similarly, for post-monsoon season RH_{min} and RH_{max} were shown significant increasing trend at 99% and 90% level of significance with and magnitude of 0.25%/year and 0.07%/year, respectively.

Seasonal trend statistics of wind speed for the Dapoli region are also presented in Table 3. From Table 3 it indicates that trend of wind speed for all the seasons exhibited a significant decreasing trend except southwest monsoon season there was no significant trend for wind speed in the southwest monsoon season. Winter, pre-monsoon, and post-monsoon seasons showed significant decreasing trends at 99%, 99.9%, and 90% levels of significance, and the trend magnitude was -0.01 km/hr/year, -0.02 km/hr/year, and -0.01 km/hr/year, respectively.

Similarly, seasonal trend statistics of SSH for the Dapoli region are presented in Table 3. Table 3 revealed that SSH showed a significant decreasing trend for all seasons. For winter, pre-monsoon, southwest monsoon and post-monsoon showed a decreasing trend at 99.9%, 95%, 90%, and 99.9% levels of significance and the magnitude of trend change per year was -0.04 hr/year, -0.02 hr/year, -0.02 hr/year and -0.03 hr/year, respectively.

Seasonal trend statistics of Pan-Evp are presented in Table 3. Winter and southwest monsoon seasons exhibited a decreasing trend at 99.9% significance levels. The magnitude of trend change pre-year for winter and southwest monsoon seasons was -1.93 mm/year and -1.6 mm/year, respectively. Pre-monsoon and post-monsoon seasons increased at 99.9% significance levels with a magnitude of 3.46 mm/year and 3.23 mm/year, respectively.

No significant trend was found for rainfall in all the seasons over the Dapoli region.

Table 3: Trend analysis of climatic parameters

Weather Parameters	Trend Statistics	Annual	Seasons			
			Winter (Jan-Feb)	Pre-Monsoon (March-May)	Southwest-Monsoon (Jun-Sept)	Post-Monsoon (Oct-Dec)
Tmin (℃)	MK-Z	4.62***	3.34***	3.28**	2.63**	4.30***
	Q	0.05	0.06	0.05	0.02	0.07
	Trend	Increasing	Increasing	Increasing	Increasing	Increasing
Tmax (℃)	MK-Z	4.90***	2.26*	3.81***	3.75***	2.89**
	Q	0.03	0.03	0.04	0.03	0.02
	Trend	Increasing	Increasing	Increasing	Increasing	Increasing
RHmin (%)	MK-Z	3.36***	3.91***	1.45	2.86**	2.84**
	Q	0.19	0.44	0.11	0.14	0.25
	Trend	Increasing	Increasing	No Trend	Increasing	Increasing
RHmax (%)	MK-Z	2.13*	1.56	1.32	2.39*	1.77+
	Q	0.07	0.06	0.05	0.08	0.07
	Trend	Increasing	No Trend	No Trend	Increasing	Increasing
Wind speed (Km/hr)	MK-Z	-2.11*	-3.00**	-3.31***	-0.77	-1.82+
	Q	-0.01	-0.01	-0.02	-0.01	-0.01
	Trend	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing
SSH (hrs)	MK-Z	-3.73***	-3.68***	-2.39*	-1.84+	-3.78***
	Q	-0.03	-0.04	-0.02	-0.02	-0.03
	Trend	Decreasing	Decreasing	Decreasing	Decreasing	Decreasing
PAN-EVP (mm)	MK-Z	0.07	-8.70***	8.67***	-8.35***	8.70***
	Q	0.19	-1.93	3.46	-1.6	3.23
	Trend	No Trend	Decreasing	Increasing	Decreasing	Increasing
Rainfall (mm)	MK-Z	1.56	-0.84	0.12	1.63	0.43
	Q	28.45	0	0	24.7	0.71
	Trend	No Trend	No Trend	No Trend	No Trend	No Trend

Note: *** trend at α= 99.9% level of significance; ** trend at α= 99% level of significance; * trend at α= 95% level of significance; + trend at α=90% level of significance

4. Conclusions

The results indicated that the minimum and maximum temperatures increased significantly on an annual and seasonal basis. Minimum relative humidity showed a significantly increasing trend on an annual and seasonal basis, while no trend occurred during the Pre-monsoon season. Maximum relative humidity significantly increased during the southwest monsoon and post-monsoon seasons, while it was no significant trend during winter and pre-monsoon seasons. Wind speed and sunshine duration shown a significantly decreasing trend on an annual and seasonal basis. Pan-evaporation increased significantly during pre-monsoon and post-monsoon while decreasing during winter and southwest monsoon seasons. Rainfall was no significant trend on an annual and seasonal basis.

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