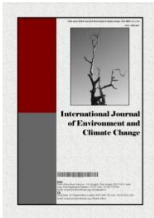

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Trend Analysis of Precipitation and Temperature over Different Districts of Karnataka: An Aid to Climate Change Detection and Cropping System Option

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Authors' contributions

The present work has come out with equal efforts among all authors. Author SS designed the study, wrote the protocol and drafted the manuscript. Author PG has performed data analysis, proofread and managed the flow of drafted manuscript. Author RN assisted in data analysis and tabulation work. All the authors read and approved the final manuscript.

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ABSTRACT

Aims: To know the rainfall and temperature trend for all the districts of Karnataka state to develop suitable coping mechanisms for changing weather conditions during the cropping season.
Study Design: The available daily data of rainfall (1971-2011) and minimum and maximum temperature (1971-2007) for each district was collected from NICRA-ICAR website. A non-parametric model such as the Mann-Kendall (MK) test complemented with Sen's slope estimator was used to determine the magnitude of the trend.
Place and Duration of Study: The rainfall data of 41 years (1971-2011) and temperature data of 37 years (1971-2007) was collected for all 27 districts of Karnataka.
Methodology: Basic statistics related to rainfall like mean, standard deviation (SD), the coefficient of variation (CV) and the percentage contribution to annual rainfall were computed for monthly and season-wise. Mann-Kendall test was used to detect trend for rainfall as well as temperature.

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Results: An increasing trend in rainfall during winter, monsoon and annual basis for all most all the districts of Karnataka and decreasing trend of rainfall during pre and post-monsoon season was noticed. An early cessation of rainfall during September month in all most all the districts of Karnataka was observed. Similarly, monthly mean, maximum and the minimum temperature had shown an increasing trend over the past 37 years for all the districts of Karnataka.
Conclusion: The more variation in rainfall during the pre-monsoon season was observed, which is more important for land preparation and other operations. The increasing trend of maximum and minimum temperature throughout the year may often cause a reduction in crop yield. It is necessary to change crops with its short duration varieties in order to avoid late season drought.

Keywords: Mann-kendall test; rainfall; temperature; Sen's slope; trend analysis.

1. INTRODUCTION

Karnataka witnesses dynamic and erratic weather that changes from place to place within its territory. Due to its varying geographic and physio-graphic conditions, Karnataka experiences climatic variations that range from arid to semi-arid in the plateau region, sub-humid to humid tropical in the Western Ghats and humid tropical monsoon in the coastal plains. More than 75 percent of the entire geographical area of Karnataka, including interior Karnataka, witnesses arid or semi-arid climate. Karnataka has about 15 percent of the total semi-arid or 3 percent of the total arid areas marked in India. Normal rainfall distribution of state varies with 731 mm in north interior Karnataka to 3456 mm in coastal Karnataka [1].The average high temperature during summer is 34°C across the state. The average day temperature is 29°C in the monsoon season. During winter, temperatures range from 32°C to below 20°C. The analysis of long-term changes in climatic variables helps in detection of climate change. Agriculture in Karnataka mainly depends on South-West monsoon followed by North-East monsoon in few districts. Apart from this Karnataka ranks second with respect to the area under dryland in the country. Rainfall is one of the most decisive weather parameters for the detection of climate change [2]. Any change in the climate during monsoon months severely affects the agricultural production, economy as well as water availability during non-monsoon months thus systematic and instant attention needs to be taken towards variability in rainfall [3]. Understanding the changing trends of climate helps us in developing suitable coping mechanisms. Although many studies have been conducted on climatic trends and spatial variations which are necessary to anticipate future impacts of climate change [4,5], only a few attempts have been made to study the trends of climatic change in Karnataka state. Hence, in the present investigation, the detailed study was made to understand the trends of changing climate over all the districts of Karnataka to develop suitable coping mechanisms for changing weather conditions during the cropping season.

2. METHODOLOGY

2.1 Data Collection and Analysis

The available daily data of rainfall (1971-2011) and minimum and maximum temperature (1971-2007) for each district was collected from NICRA-ICAR website.Basic statistics related to rainfall like mean, standard deviation (SD), the coefficient of variation (CV) and the percentage contribution to annual rainfall were computed for monthly and season-wise *viz*., winter (January-February), Pre-monsoon (March-May), Monsoon (June-September) and Post-monsoon (October-December).

2.2 Non-parametric Test

Mann Kendall test is a statistical test widely used for the analysis of trend in climatologic [6] and in hydrologic time series [7]. There are two advantages of using this test. First, it is a non parametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series [8]. Any data reported as non-detects are included by assigning them a common value that is smaller than the smallest measured value in the data set. According to this test, the null hypothesis H_0 assumes that there is no trend (the data is independent and randomly ordered) and this is tested against the alternative hypothesis H_1 which assumes that there is a trend [9].

The computational procedure for the Mann Kendall test considers the time series of n data points and T_i and T_j as two subsets of data where i = 1,2,3,…, n-1 and j = i+1, i+2, i+3, …, n. The data values are evaluated as an ordered time series. Each data value is compared with all subsequent data values. If a data value from a later time period is higher than a data value from an earlier time period, the statistic *S* is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, *S* is decremented by 1. The net result of all such increments and decrements yields the final value of *S* [10].

The Mann-Kendall S Statistic is computed as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign\,(Tj - Ti)$$

$$Sign\,(T_j - T_i) = \begin{cases} 1\; if Tj - Ti > 0 \\ 0\; if Tj - Ti = 0 \\ -1\; if Tj - Ti < 0 \end{cases}$$

Where, T_j and T_i are the annual values in years j and i, j >i, respectively [11]. If n < 10, the value of S derived by Mann and Kendall. The two tailed test is used. At certain probability level H_0 is rejected in favor of H_1, if the absolute value of S equals or exceeds a specified value of $S_{\alpha/2}$ where $S_{\alpha/2}$ is the smallest S which has the probability less than α/2 to appear in case of no trend. A positive (negative) value of S indicates an upward (downward) trend. For n ≥ 10, the statistic *S* is approximately normally distributed with the mean and variance as follows:

E(S) = 0

The variance (σ^2) for the S-statistic is defined by:

$$\sigma^2 = \frac{n(n-1)(2n+5) - (\Sigma ti(i)(i-1)(2i+5)}{18}$$

In which t_i denotes the number of ties to extent i. The summation term in the numerator is used only if the data series contains tied values. The standard test statistic Z_s is calculated as follows:

$$Z_s = \begin{cases} \frac{S-1}{\sigma}\; for\; S > 0 \\ 0\; for\; S = 0 \\ \frac{S+1}{\sigma}\; for\; S < 0 \end{cases}$$

The test statistic Zs is used a measure of significance of trend. In fact, this test statistic is used to test the null hypothesis, H_0 If $|Z_s|$ is greater than $Z_{\alpha/2}$, where a represents the chosen significance level (eg: 5% with $Z_{0.025}$ = 1.96) then the null hypothesis is invalid implying that the trend is significant.

Another statistic obtained on running the Mann-Kendall test is Kendall's tau, which is a measure of correlation and therefore measures the strength of the relationship between the two variables. Kendall's tau, like Spearman's rank correlation, is carried out on the ranks of the data. That is, for each variable separately, the values are put in order and numbered, 1 for the lowest value, 2 for the next lowest and so on. In common with other measures of correlation, Kendall's tau will take values between ±1 and +1, with a positive correlation indicating that the ranks of both variables increase together whilst a negative correlation indicates that as the rank of one variable increases, the other decreases.

In time series analysis it is essential to consider autocorrelation or serial correlation, defined as the correlation of a variable with itself over successive time intervals, prior to testing for trends. Autocorrelation increases the chances of detecting significant trends even if they are absent and vice versa. In order to consider the effect of autocorrelation, [12] suggest a modified Mann-Kendall test, which calculates the autocorrelation between the ranks of the data after removing the apparent trend. The adjusted variance is given by:

$$\text{Var}[S] = \frac{1}{18}[N(N-1)(2N+5)]\frac{N}{NS*}$$

Where $\frac{N}{NS*} = 1 + \frac{2}{N(N-1)(N-2)}\sum_{i=1}^{p}(N-i)(N-i-1N-i-2ps(i)$

N is the number of observations in the sample, NS* is the effective number of observations to account for autocorrelation in the data, ps (i) is the autocorrelation between ranks of the observations for lag i, and p is the maximum time lag under consideration.

Software used for performing the statistical Mann-Kendall test is Addinsoft’s XLSTAT2012. The null hypothesis is tested at 95% confidence level for both, temperature and precipitation data for the nine states. In addition, to compare the results obtained from the Mann-Kendall test, linear trend lines are plotted for each state using Microsoft Excel 2007.

2.3 Sources of Error

No information is available about the number of precipitation gauges and temperature sensors used in each state to record precipitation and temperature data. Also, the exact location of these gauges and sensors is unknown. The lack of uniformity in precipitation gauges and temperature sensors can influence the quality of recorded data.

National Climatic Data Center Website also mentions that due to problems in data transmission by each station location, errors might be observed in the data. Though quality control is performed, but a 100% correction rate is not possible [13].

Non-Parametric statistics are usually much less affected by the presence of outliers and other forms of non-normality [14] and represent a measure of monotonic linear dependence [15], [16]. The most frequently used non-parametric test for identifying trends in hydrologic variables is the Mann-Kendall (MK) test [17,18]. This test can overcome the influence of extremes and missing values in the data set [19,20]. The statistical significance trend detected using a non-parametric model such as the Mann-Kendall (MK) test can be complemented with Sen's slope estimation to determine the magnitude of the trend [21]. MK test and Sen's slope estimator tests are the most suitable methods for the detection of hydrological and meteorological trend [22].

2.4 Level of Significance (p-value)

The level of significance was considered at a p-value of 0.1, 0.05, 0.01, 0.001 and mentioned with +, *, ** and *** notations respectively.

3. RESULTS AND DISCUSSION

Karnataka state receives an annual average rainfall of 1314.9 mm. However, the highest rainfall of 1722.4 mm was received during 2006 and the lowest (980.6 mm) during 1976 (Fig. 1). The coastal district of Dakshina Kannada recorded the highest annual average rainfall (3846.2 mm). Meanwhile, lowest annual rainfall of 503.2 mm was received in Chitradurga district. Hence, the Karnataka government, as well as district administration, must be prepared to face the drought well in advance *i.e*. every second pentad. The annual as well as the seasonal basis of trend and slope of rainfall and temperature in all 27 districts of Karnataka has been worked out and presented hereunder.

3.1 Seasonal and Annual Trends of Rainfall over Different Districts of Karnataka

3.1.1 Winter-season

All the 27 districts of Karnataka had shown an increasing trend during the winter season over the past 41 years time period (Table 1).

3.1.2 Pre-monsoon season

Among the 27 districts, 16 districts shown an increasing trend (Table 1). However, Bengaluru urban, Bengaluru rural, Belgaum, Chamarajanagar, Dakshina Kannada, Hassan, Gadag, Kodagu, Mandya and Mysuru had shown

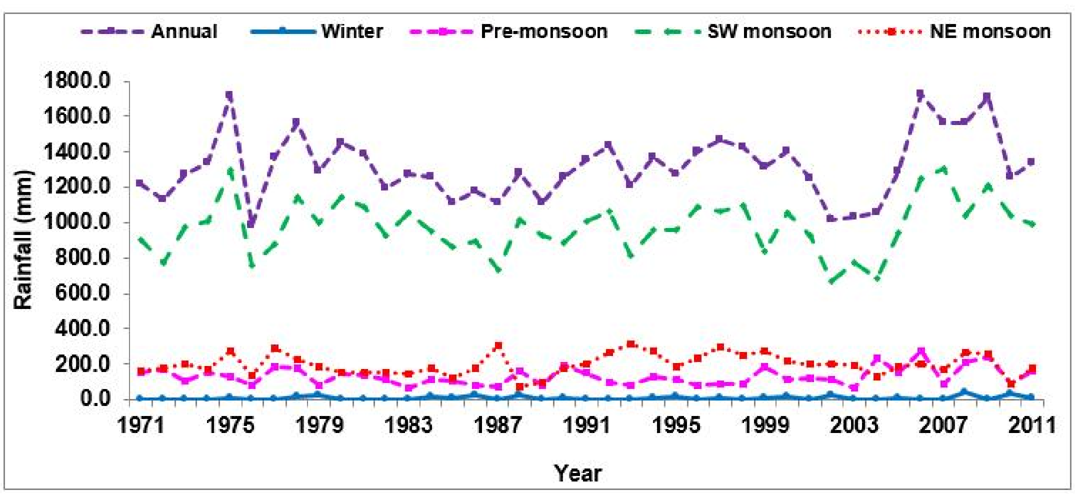

Fig. 1. Annual and seasonal rainfall of Karnataka from 1971 to 2011

a negative trend over 41 years. Bidar district did not show either negative or positive trend during pre-monsoon season.

3.1.3 Monsoon season

During monsoon season most of the districts had shown a positive trend (Table 1) except Bidar, Chamarajanagar, Dakshina Kannada and Kodagu district which showed the negative trend over the past 41 years.

3.1.4 Post monsoon season

In the post-monsoon season over the past 41 years (Table 1) 18 districts of Karnataka had shown an increasing trend. Whereas, Bengaluru urban, Bengaluru rural, Vijayapura, Dakshina Kannada, Kalburgi, Kodagu, Kolar and Raichur showed a decreasing trend. However, Bidar district had shown the decreasing trend at 95% of the significance level.

3.1.5 Annual

All the districts of Karnataka had shown an increasing trend of annual rainfall over the last 41 years and a negative trend was noticed over Bidar, Chamarajanagar, Dakshina Kannada and Kodagu districts (Table 1). The present findings are in corroboration with the studies of Kumar et al., 2010, who has analyzed 135 years of rainfall data and indicated a significant increasing trend in annual rainfall of Karnataka. Significant reduction in annual, as well as seasonal rainfall particularly highest rainfall receiving coastal district like Dakshina Kannada may experience uneven distribution of rainfall and an early shortfall of soil moisture for paddy and horticultural crops. Singh et al. (2014) analyzed climatic variability for coastal Karnataka and

Table 1. Mann Kendall test (Z) and Sen's slope (Q) for precipitation

Districts	Annual		Winter (Jan-Feb)		Pre-monsoon (Mar-May)		Monsoon (June-Sept)		Post monsoon (Oct-Dec)	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
Bagalkote	↑	0.60	↑	0.00	↑	0.18	↑	0.58	↑	0.25
Belgaum	↑	4.74	↑	0.00	↓	-0.11	↑	4.22	↑	0.25
Bellary	↑*	4.35	↑*	0.03	↑	0.83	↑	2.60	↑	1.26
Bidar	↓	-5.13	↑	0.00	↔	-0.01	↓	-2.34	↓*	-2.10
Dharwad	↑	3.65	↑	0.00	↑	0.05	↑	1.73	↑	0.84
Gadag	↑	2.26	↑	0.00	↓	-0.03	↑	1.32	↑	0.72
Haveri	↑+	5.05	↑	0.00	↑	0.60	↑	3.37	↑	0.79
Kalburgi	↑	0.17	↑	0.03	↑	0.10	↑	1.81	↓	-1.38
Koppal	↑+	4.36	↑	0.00	↑	0.78	↑	2.39	↑	0.98
Raichur	↑	2.41	↑	0.02	↑	0.46	↑	1.90	↓	-0.12
Vijayapura	↑	0.78	↑	0.00	↑	0.34	↑	0.70	↓	-0.42
Bengaluru (Rural)	↑	1.50	↑+	0.04	↓	-0.93	↑	2.90	↓	-0.60
Bengaluru (Urban)	↑	1.09	↑+	0.04	↓	-0.09	↑	2.49	↓	-0.67
Chamarajanagar	↓	-3.49	↑	0.07	↓	-0.64	↓	-4.31	↑	0.83
Chikkamagaluru	↑	3.29	↑	0.00	↑	0.56	↑	0.58	↑	1.81
Chitradurga	↑+	5.44	↑*	0.00	↑	0.78	↑	2.77	↑+	1.70
Davanagere	↑+	4.87	↑+	0.00	↑	0.96	↑	2.54	↑	1.25
Hassan	↑	2.64	↑	0.02	↓	-0.19	↑	0.86	↑	1.57
Kodagu	↓+	-13.05	↑+	0.03	↓	-0.82	↓	-14.53	↓	-0.79
Kolar	↑	2.78	↑	0.01	↑	0.87	↑+	2.98	↓	-1.38
Mandya	↑*	5.74	↑+	0.01	↓	-0.54	↑	3.04	↑	1.41
Mysuru	↑	5.07	↑*	0.07	↓	-0.31	↑	1.29	↑*	2.52
Shivamogga	↑	7.22	↑	0.01	↑	1.47	↑	4.22	↑	1.37
Tumkur	↑	4.58	↑	0.01	↑	0.77	↑+	4.26	↑	0.60
Dakshina Kannada	↓	-12.14	↑	0.02	↓	-0.16	↓	-10.35	↓	-0.32
Udupi	↑	5.20	↑	0.00	↑	1.80	↑	1.84	↑+	2.63
Uttara Kannada	↑*	15.91	↑	0.00	↑	1.54	↑	9.86	↑	1.07

Where, (↑) Indicates increasing trend;(↓) Indicates decreasing trend;
*(↔) No change in trend; *0.05 level of significance; + 0.1 level of significance*

stated that decreasing trend in rainfall at the rate of 1.62 mm/year. Similarly, the hilly district, like Kodagu, had shown a declining trend of rainfall might result in a substantial reductionof the productivity of plantation as well as horticultural crops.

3.2 Monthly Rainfall Trends during South-West Monsoon over Different Districts of Karnataka

North Interior Karnataka (NIK) districts like Bidar, Dharwad and Belgaum had shown decreasing trend of rainfall during June and July months (Table 2) indicating the trends of delayed onset of rainfall which in turn results in decreasing area under soybean, greengram, blackgram, pigeonpea or postponement of sowing. Most of the districts of NIK shown the decreasing trend for precipitation during September, excluding Belgaum, Dharwad, Haveri, Kalburgi and Raichur. These resulted in decreasing the area of rabi sown crops like sorghum and chickpea. Sufficient harvest of pre-monsoon showers, selection of short duration varieties and soil moisture conservation practices need to be undertaken in order to overcome the moisture stress.

During monsoon season, South Interior Karnataka (SIK) districts like Chamarajanagar, Chikkamagaluru, Kodagu, Shivamogga and Hassan had shown a decreasing trend of rainfall during June, July and August months. Late onset of monsoon and uneven distribution of rainfall may result in a postponement of sowing time and a drastic reduction in yield of ragi, potato, maize and pulses due to the occurrence of frequent dry spells in July month. Similarly, during September month all most all districts of SIK had shown decreasing trend except Chikkamagaluru, Davanagere and Shivamogga. Reduction in frequency of occurrence of rainfall events during September month may adversely affect the yield

Table 2. Mann Kendall test (Z) and Sen's slope (Q) for monthly precipitation during south-west monsoon season

Districts	S-W monsoon		June		July		August		September	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
Bagalkote	↑	0.58	↑	0.84	↑	0.22	↑*	1.13	↓	-0.55
Belgaum	↑	4.22	↑	0.88	↓	-0.33	↑+	1.51	↑	-1.15
Bellary	↑	2.60	↑	0.51	↑	0.72	↑**	1.81	↓	-0.71
Bidar	↓	-2.34	↓	-0.55	↓	-0.89	↑	0.31	↓	-0.10
Dharwad	↑	1.73	↓	-0.28	↑	0.43	↑*	1.46	↑	0.21
Gadag	↑	1.32	↑	0.11	↑	0.32	↑**	1.70	↓	-0.83
Haveri	↑	3.37	↑	0.74	↑	0.86	↑*	1.79	↑	0.06
Kalburgi	↑	1.81	↑	0.19	↑	0.05	↑	1.32	↑	0.62
Koppal	↑	2.39	↑	0.36	↑	0.55	↑*	1.74	↓	-1.19
Raichur	↑	1.90	↑	0.34	↑	0.20	↑	1.62	↑	0.25
Vijayapura	↑	0.70	↑	0.0	↑	0.34	↑	0.70	↓	-0.42
Bengaluru (Rural)	↑	2.90	↑+	1.13	↑	0.64	↑*	2.04	↓	-1.35
Bengaluru (Urban)	↑	2.49	↑+	1.05	↑	0.66	↑*	2.09	↓	-1.44
Chamarajanagar	↓	-4.31	↓	-0.68	↓	-1.16	↓+	-1.97	↓+	-1.55
Chikkamagaluru	↑	0.58	↓	-1.59	↓	-0.72	↓	-0.08	↑	0.99
Chitradurga	↑	2.77	↑	0.40	↑*	0.76	↑***	1.97	↓	-0.84
Davanagere	↑	2.54	↑	0.45	↑	0.80	↑**	1.89	↑	0.22
Hassan	↑	0.86	↑	0.19	↓	-1.09	↑	1.42	↓	-0.42
Kodagu	↓	-14.53	↓	-1.51	↓*	-7.32	↓	-2.96	↓	-2.71
Kolar	↑+	2.98	↑*	0.94	↑	0.72	↑+	1.52	↓	-0.31
Mandya	↑	3.04	↑	0.90	↑+	0.94	↑**	2.15	↓	-0.43
Mysuru	↑	1.29	↑	0.66	↑	0.05	↑	0.50	↓	-0.27
Shivamogga	↑	4.22	↓	-0.13	↓	-0.53	↑	0.71	↑	1.88
Tumkur	↑+	4.26	↑*	0.97	↑*	1.04	↑**	2.15	↓	-1.05
Dakshina Kannada	↓	-10.35	↓	-1.82	↓*	-6.48	↓	-3.54	↓	-0.84
Udupi	↑	1.84	↓	-1.93	↓	-4.88	↓	-2.34	↑*	-1.28
Uttara Kannada	↑	9.86	↑	0.95	↓	-1.25	↑	3.38	↑*	4.24

Where, (↑) Indicates increasing trend; (↓) Indicates decreasing trend;
****0.001 level of significance; **0.01 level of significance; *0.05 level of significance; + 0.1 level of significance*

of standing crops like maize, ragi, tobacco and pulses. Mid season corrections like thinning, foliar spray of nutrients, life-saving irrigation may be the plausible options to overcome these stress conditions.

Dakshina Kannada district had shown a decreasing trend of rainfall for all the months during monsoon season followed by Udupi districts in June, July and August months indicating the non-availability of water for rainfed rice as well as the outbreak of pests and diseases in important plantation crops like cashew and arecanut.

3.3 Temperature (°C)

3.3.1 Winter-season

Maximum temperature had shown increasing trend during the winter season for all the 27 districts of Karnataka (Table 3). Whereas minimum temperature showed an increased trend in 23 districts and remaining four districts *viz.,*Bagalkote, Bidar, Vijayapura and Kalburgi noticed a decreasing trend (Table 4). Similarly, mean temperature during winter season all most all the districts noticed an increasing trend (Table 5). The decreasing trend of minimum temperature coupled with higher relative humidity in few districts of NIK leads to increased incidence of foliar diseases in sorghum, chickpea and wheat.

3.3.2 Pre-monsoon season

During pre-monsoon season trend for maximum temperature was increasing for all most all the districts except Bengaluru rural, Bengaluru urban and Mandya (Table 3). Whereas, minimum temperature trend increased for 21 districts (Table 4) while a decreasing trend was observed

Table 3. Mann Kendall test (Z) and for maximum temperature (°C)

Districts	Annual		Winter (Jan-Feb)		Pre-monsoon (Mar-May)		Monsoon (June-Sept)		Post monsoon (Oct-Dec)	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
Bagalkote	↑***	0.018	↑**	0.026	↑	0.016	↑	0.015	↑	0.031
Belgaum	↑***	0.017	↑**	0.027	↑+	0.014	↑	0.014	↑	0.015
Bellary	↑**	0.014	↑***	0.032	↑	0.009	↑	0.014	↑	0.011
Bidar	↑*	0.015	↑*	0.028	↑	0.008	↓	-0.001	↑**	0.036
Dharwad	↑***	0.017	↑***	0.029	↑*	0.017	↑*	0.017	↑*	0.022
Gadag	↑***	0.018	↑***	0.031	↑*	0.018	↑*	0.016	↑*	0.023
Haveri	↑***	0.015	↑***	0.033	↑	0.011	↑*	0.020	↑+	0.018
Kalburgi	↑**	0.018	↑**	0.028	↑	0.012	↑	0.005	↑**	0.037
Koppal	↑***	0.022	↑***	0.032	↑+	0.016	↑+	0.014	↑*	0.030
Raichur	↑***	0.021	↑**	0.032	↑+	0.017	↑	0.012	↑**	0.035
Vijayapura	↑***	0.018	↑*	0.027	↑	0.015	↑	0.009	↑**	0.035
Bengaluru (Rural)	↑	0.005	↑*	0.021	↓	-0.006	↑	0.013	↓	-0.003
Bengaluru (Urban)	↑	0.005	↑*	0.021	↓	-0.006	↑	0.013	↓	-0.004
Chamarajanagar	↑	0.008	↑*	0.018	↑	0.001	↑+	0.013	↑	0.005
Chikkamagaluru	↑***	0.015	↑***	0.032	↑	0.006	↑*	0.016	↑*	0.018
Chitradurga	↑**	0.013	↑**	0.030	↑	0.003	↑+	0.016	↑*	0.021
Davanagere	↑***	0.015	↑***	0.032	↑	0.007	↑*	0.019	↑+	0.019
Hassan	↑**	0.013	↑**	0.027	↑	0.004	↑*	0.016	↑+	0.012
Kodagu	↑***	0.016	↑***	0.028	↑	0.005	↑**	0.022	↑*	0.016
Kolar	↑*	0.011	↑**	0.024	↑	0.008	↑+	0.015	↑	0.009
Mandya	↑*	0.012	↑**	0.022	↓	-0.001	↑*	0.017	↑	0.009
Mysuru	↑*	0.011	↑**	0.023	↑	0.001	↑*	0.018	↑	0.010
Shivamogga	↑***	0.016	↑***	0.034	↑	0.010	↑*	0.019	↑*	0.017
Tumkur	↑**	0.011	↑**	0.027	↑	0.001	↑*	0.014	↑+	0.014
Dakshina Kannada	↑***	0.016	↑***	0.031	↑	0.007	↑*	0.021	↑**	0.018
Udupi	↑***	0.019	↑***	0.037	↑+	0.013	↑*	0.019	↑**	0.019
Uttara Kannada	↑***	0.015	↑***	0.025	↑+	0.014	↑*	0.018	↑*	0.015

Where, (↑) Indicates increasing trend; (↓) Indicates decreasing trend;
****0.001 level of significance; **0.01 level of significance; *0.05 level of significance; + 0.1 level of significance*

in Bagalkote, Belgaum, Bidar, Vijayapura, Kalburgi and Uttara Kannada. In the case of mean temperature, all the districts of Karnataka had shown an increasing trend during pre-monsoon season (Table 5). Significant increase in maximum temperature during summer months causes pollen abortion and increases water loss through evapo-transpiration.

3.3.3 Monsoon season

All the districts of Karnataka had shown an increasing trend of maximum temperature except Bidar during monsoon season (Table 3). Similarly, minimum temperature also follows an increasing trend during monsoon season. However, Bagalkote and Vijayapura districts noticed a decreasing trend of minimum temperature (Table 4). All the districts during monsoon season had shown an increasing trend of mean temperature (Table 5).

3.3.4 Post monsoon season

Increasing trend of maximum temperature during the post monsoon season was observed (Table 3) for most of the districts of Karnataka except Bengaluru rural and Bengaluru urban. Whereas, minimum temperature had shown increasing trend only in 9 districts and remaining districts are in decreasing trend during post monsoon season (Table 4). Similarly, the mean temperature had shown an increasing trend in all most all the districts except Bengaluru (Rural and urban), Belgaum and Bellary districts over past 37 years of time series (Table 5). Decrease in minimum and mean temperature in NIK districts it extends the germination period of rabi sorghum and chickpea also prolongs flowering period

Table 4. Mann Kendall test (Z) and Sen's slope (Q) for minimum temperature (°C)

Districts	Annual		Winter (Jan-Feb)		Pre-monsoon (Mar-May)		Monsoon (June-Sept)		Post monsoon (Oct- Dec)	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
Bagalkote	↓+	-0.014	↓	-0.001	↓	-0.004	↓	-0.003	↓*	-0.029
Belgaum	↓	-0.009	↑	0.005	↓	0.000	↑	0.003	↓*	-0.023
Bellary	↓	-0.001	↑	0.002	↑	0.011	↑	0.005	↓	-0.019
Bidar	↓	-0.002	↓	-0.005	↓	-0.005	↑	0.007	↓	-0.012
Dharwad	↑	0.003	↑	0.009	↑	0.000	↑+	0.008	↓	-0.001
Gadag	↑	0.002	↑	0.009	↑	0.001	↑	0.008	↑	0.000
Haveri	↑	0.006	↑	0.010	↑	0.003	↑	0.007	↑	0.001
Kalburgi	↓	-0.003	↓	-0.005	↓	-0.001	↑	0.006	↓	-0.013
Koppal	↓	0.001	↑	0.000	↑	0.004	↑	0.002	↓	0.008
Raichur	↓	0.000	↑	0.001	↑	0.005	↑	0.005	↓	-0.010
Vijayapura	↓	-0.007	↓	-0.002	↓	-0.007	↓	-0.002	↓	-0.017
Bengaluru (Rural)	↑+	0.011	↑+	0.026	↑+	0.017	↑***	0.018	↓	-0.001
Bengaluru (Urban)	↑+	0.012	↑+	0.027	↑+	0.017	↑***	0.019	↓	0.000
Chamarajanagar	↑***	0.019	↑*	0.029	↑**	0.019	↑***	0.016	↑	0.009
Chikkamagaluru	↑	0.007	↑	0.008	↑	0.006	↑	0.007	↓	-0.004
Chitradurga	↑	0.005	↑	0.007	↑	0.008	↑	0.006	↓	-0.003
Davanagere	↑	0.005	↑	0.006	↑	0.004	↑	0.006	↓	-0.001
Hassan	↑	0.008	↑	0.008	↑	0.009	↑**	0.014	↑	0.001
Kodagu	↑	0.008	↑	0.013	↑	0.007	↑+	0.010	↑	0.000
Kolar	↑+	0.010	↑	0.019	↑+	0.018	↑**	0.013	↑	0.006
Mandya	↑**	0.016	↑	0.023	↑*	0.016	↑***	0.019	↑	0.008
Mysuru	↑**	0.016	↑+	0.022	↑*	0.015	↑***	0.018	↑	0.008
Shivamogga	↑	0.005	↑	0.007	↑	0.003	↑	0.007	↓	-0.003
Tumkur	↑*	0.010	↑	0.014	↑+	0.015	↑**	0.012	↑	0.001
Dakshina Kannada	↑	0.007	↑	0.009	↑	0.008	↑	0.008	↓	-0.004
Udupi	↑	0.006	↑	0.005	↑	0.003	↑	0.010	↓	-0.002
Uttara Kannada	↑	0.005	↑	0.007	↓	-0.003	↑	0.006	↓	-0.004

Where, (↑) Indicates increasing trend; (↓) Indicates decreasing trend;
****0.001 level of significance; **0.01 level of significance; *0.05 level of significance; +0.1 level of significance*

Table 5. Mann Kendall test (Z) and Sen's slope (Q) for mean temperature (°C)

Districts	Annual		Winter (Jan-Feb)		Pre-monsoon (Mar-May)		Monsoon (June-Sept)		Post monsoon (Oct- Dec)	
	Z	Q	Z	Q	Z	Q	Z	Q	Z	Q
Bagalkote	↑	0.005	↑	0.011	↑	0.005	↑	0.008	↑	0.004
Belgaum	↑	0.004	↑*	0.012	↑	0.005	↑	0.008	↓	-0.007
Bellary	↑	0.005	↑	0.015	↑	0.010	↑	0.007	↓	-0.003
Bidar	↑	0.005	↑	0.009	↑	0.003	↑	0.003	↑	0.015
Dharwad	↑*	0.010	↑*	0.017	↑	0.007	↑**	0.011	↑	0.007
Gadag	↑***	0.018	↑***	0.031	↑*	0.018	↑*	0.016	↑*	0.023
Haveri	↑*	0.011	↑*	0.018	↑	0.007	↑*	0.011	↑	0.007
Kalburgi	↑	0.007	↑	0.011	↑	0.007	↑	0.005	↑	0.012
Koppal	↑	0.008	↑	0.014	↑	0.012	↑	0.009	↑	0.008
Raichur	↑	0.009	↑	0.015	↑	0.012	↑	0.007	↑	0.013
Vijayapura	↑	0.004	↑	0.011	↑	0.004	↑	0.005	↑	0.005
Bengaluru (Rural)	↑+	0.007	↑**	0.022	↑	0.003	↑*	0.014	↓	-0.004
Bengaluru (Urban)	↑+	0.008	↑**	0.023	↑	0.003	↑*	0.014	↓	-0.004
Chamarajanagar	↑**	0.013	↑**	0.021	↑	0.009	↑**	0.013	↑	0.006
Chikkamagaluru	↑**	0.012	↑*	0.017	↑	0.004	↑*	0.013	↑	0.005
Chitradurga	↑+	0.010	↑+	0.017	↑	0.007	↑*	0.011	↑	0.007
Davanagere	↑*	0.011	↑+	0.018	↑	0.005	↑*	0.011	↑	0.006
Hassan	↑**	0.010	↑*	0.018	↑	0.005	↑**	0.015	↑	0.003
Kodagu	↑**	0.012	↑*	0.018	↑	0.004	↑**	0.015	↑	0.005
Kolar	↑*	0.011	↑*	0.020	↑	0.012	↑*	0.014	↑	0.006
Mandya	↑**	0.012	↑*	0.021	↑	0.007	↑***	0.016	↑	0.006
Mysuru	↑***	0.013	↑*	0.019	↑	0.007	↑***	0.018	↑	0.006
Shivamogga	↑***	0.016	↑***	0.034	↑	0.010	↑*	0.019	↑*	0.017
Tumkur	↑**	0.011	↑*	0.018	↑	0.006	↑*	0.011	↑	0.004
Dakshina Kannada	↑**	0.012	↑*	0.018	↑	0.005	↑*	0.016	↑	0.006
Udupi	↑**	0.013	↑**	0.021	↑	0.007	↑*	0.015	↑	0.007
Uttara Kannada	↑*	0.010	↑**	0.016	↑	0.005	↑*	0.011	↑	0.005

Where, (↑) Indicates increasing trend; (↓) Indicates decreasing trend;
****0.001 level of significance; **0.01 level of significance; *0.05 level of significance; +0.1 level of significance*

along with the increased incidence of fungal disease at the early stages of crop growth. Similarly, in SIK districts, low temperature leads to increased incidence of pest and disease in pulses and oilseed crops.

3.3.5 Annual

The annual trend of maximum temperature throughout the year for all the districts had shown an increasing trend (Table 3) whereas in the case of minimum temperature, nine districts had shown an increasing trend and remaining districts are in decreasing trend of minimum temperature (Table 4). The mean temperature had shown an increasing trend in all the districts of Karnataka (Table 5). Warmer temperatures expected with changing climate, which in terms results in more extreme temperature events during the pollination period, which significantly affects crop production.

4. CONCLUSION

The trend analysis of rainfall over a past 41 years had shown an increasing trend during winter, monsoon and annual basis for all most all the districts of Karnataka. However, the declining trend had shown during pre-monsoon, post monsoon as well as September month during monsoon season. It is noticed that in the recent past rainfall trend during pre- monsoon and post monsoon season declines particularly in the districts benefiting from post-monsoon rainfall showers of the northern and southern part of Karnataka. The more variation in rainfall during the pre-monsoon season was observed, which is more important for land preparation and other operations. The increasing trend of maximum and minimum temperature throughout the year may often cause a reduction in crop yield. It is necessary to change crops with its short duration varieties in order to avoid late season drought and there is an urgent need for the development of temperature tolerant varieties that can be grown throughout the year.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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