

MONTHLY, SEASONAL AND ANNUAL CHANGES IN TEMPERATURE IN KARNATAKA STATE IN INDIA

Abstract

The mean annual minimum temperature during the period 1979-2019 has increased significantly in Eastern dry zone, Southern dry zone and Southern transition zone to a cumulative of total of 0.010°C, 0.013°C and 0.08 °C respectively while it has decreased significantly in Hilly zone with a magnitude of -0.032°C. The annual maximum temperature significantly increased in North eastern transition zone (0.018°C), North eastern dry zone (0.017°C), Northern dry zone (0.014°C), Central dry zone (0.010°C), Eastern dry zone (0.011°C), Southern dry zone (0.013°C), Southern transition zone (0.016°), Northern transition zone (0.016°C) and Coastal zone (0.018°C). The hilly zone experienced a decrease in annual maximum temperature by -0.055°C. Researchers should develop crop varieties that are insensitive to temperature changes and scientist should develop packages of practices which will mitigate adverse effect of fluctuations in climate parameters on crop productivity.

Key words: Climate change, Agro-climatic zones, Temperature, Shift ,Mitigate

1. Introduction

The emission of green house gases disturbs the established energy balance of atmosphere which result in rising in temperature and increased erraticity of climatic parameters. The global annual mean surface temperature has increased by more than 1.5°C above the pre industrial level (IPCC, 2018). This increase in temperature has caused unprecedented changes across the human and natural systems. In the process of gradual warming, the mean temperature shifted upward which amounts to climate change. At global level ,though total precipitation has decreased across the African continent with increasing length of consecutive dry days and decreasing length of consecutive wet days, average rainfall intensity and extreme rainfall events have decreased in western central Africa (Aguilar et al., 2009). In India, the last five decades experienced an increase in the frequency and magnitude of extreme rain events over central India, western India, north-eastern India, and southern India whereas, an increase in the frequency of severe droughts have been observed over south India, central Maharashtra, the Indo-Gangetic plains, north, and northwest India (Sharma and Majumdar, 2017).The vulnerability of a system is determined by concepts of exposure, sensitivity and adaptive capacity towards climate change.

Semi- arid region of peninsular India are vulnerable to drought and water stress due to uneven distribution of monsoon rainfall. The delay in monsoon or dry spells adds pressure on available water resources. Even in such situations farmers in semi arid India continue to grow water intensive crops. Karnataka ranks second among drought effected states after Rajasthan with frequent occurrence of droughts once in five years.

The impact of climate shock creates unequal access to resources, food insecurity and incidence of poverty in country. The risk associated with climate change calls for a broad spectrum of policy responses and strategies at the local, regional, national and global level to mitigate the effect of the same. It is, therefore, important to examine the extent of change and extremes in temperature across ten agro climatic zones of Karnataka.

2. Materials and Methodology

There are 10 agro climatic zones in Karnataka which is classified by Department of Agriculture along with University of Agricultural sciences, Bangalore during the year 2010 summarised in Table 1.

Source of Secondary Data:The daily observed data for minimum temperature (Min Temp)and maximum temperature (Max Temp)of 30 districts of Karnataka for a period of 1979 to 2019 were collected from the AICRPAM, CRIDA, Hyderabad.

The daily weather data is aggregated for 12 months, 4 climatic seasons namely, Winter (January-February),Summer (March –May), South west monsoon (SWM) (June-September) and north east monsoon (NEM) (October –December) and annual by taking simple averages for analysis.Total 34 data sets i.e., 12 months, 4 seasons and 1 annual data set of temperature were computed for each agro climatic zones. Thus, 340 data sets were obtained for 10 agro climatic zones of Karnataka to analyse Mann Kendall analysis.

Table 1: Agro-climatic zones (ACZ) of Karnataka

Dry Zones	Transition Zones	Hilly and Coastal Zones
North Eastern Dry Zone (II)	North Eastern Transition Zone (I)	Hilly Zone (IX)
Northern Dry Zone (III)	Southern Transition Zone (VII)	Coastal Zone (X)
Central Dry Zone (IV)	Northern Transition Zone (VIII)	
Eastern Dry Zone (V)		
Southern Dry Zone (VI)		

Source: Department of Agriculture &University of Agricultural Sciences, Bangalore 2010

2.1 Mann Kendall (MK) Test

Mann Kendall test is one of the most widely used methods to statistically assess the presence of significance of trend in the climatic data (Lanzante, 1996). This test compares only the relative values of sample data rather than absolute value (Modarres & Silva, 2007). In Mann Kendall test, the null hypothesis (Ho) assumes that there is no trend in the data against alternative hypothesis (H₁) which assumes that there is a trend. Software XL Stata is used for analysing the data.

Null hypothesis Ho: There is no trend in the data

Alternate hypothesis H₁: There is trend in the data

Mann Kendall S Statistic is computed as follows:

$$S = \sum_{i=1}^{n-1} \sum_{i+1}^n \text{sign}(T_j - T_i) \dots\dots\dots (1)$$

Where n represents the number of data points, and represents the data values in time series T_j and T_i such that (i>j), respectively and sign () is the sign function as;

$$\text{sign}(T_j - T_i) = \begin{cases} 1 & \text{if } T_j > T_i \\ 0 & \text{if } T_j = T_i \dots\dots\dots(2) \\ -1 & \text{if } T_j < T_i \end{cases}$$

Where T_jand T_i are the annual values in year j and i , j > I, respectively. It assumes a linear trend in the time series. The variance is computed as:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^m t_i(t_i-1)(2t_i+5)}{18} \dots\dots\dots(3)$$

Where n represents the number of data set, m is the number of ties group (sample data having the same value) and 't_i' represents the number of ties to extent 'i'. The standardized test statistic Z_s is computed using following equation:

$$Z_s = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, & \text{if } S < 0 \end{cases} \dots\dots\dots(4)$$

Z_s value indicates the nature of trend. Negative value of Z_s indicate decreasing trend while positive values indicate increasing trend (Onoz& Bayazit, 2012). Z_s is used to measure the significance of trend. Null hypothesis is tested using the test statistic Z_s values. If |Z_s| > Z_{α/2}, where α represent the chosen significance level then the null hypothesis is rejected indicating that the trend is significant (Sen, 1968). In this study null hypothesis was tested at 1%, 5% and 10% significance level. Asgheret al., (2021) examined in detail the temperature of Bhaderwah meteorological station from 1980 to 2017 by applying Mann Kendall test on mean monthly maximum temperature data. The Z_s statistic value reveals the trend of mean monthly maximum temperature for individual months from January to December which are -0.243, 0.016, 1.364, -0.130, 0.535, - 1.867, -0.138, -2.306, -1.494, -0.325, -1.379 and -0.746, respectively

2.2 Sen's slope estimator

Sen's slope estimator is a non-parametric procedure which is used for estimating the magnitude of trend in the sample of N pairs of data (Tabari & Talae, 2011).

$$Q_i = \frac{x_k - x_j}{k - j} \text{ for } i = 1 \dots N \dots\dots\dots(5)$$

Where X_k and X_j represents the data values at times j and k such that j > k, respectively. The median of N values of Q_i is Sen's estimator of slope which is computed as:

$$Q = \begin{cases} Q_{\frac{N+1}{2}}, & \text{if } N \text{ is Odd} \\ \frac{1}{2} \left(Q_{\frac{N}{2}} + Q_{\frac{N+1}{2}} \right) & \text{if } N \text{ is even} \end{cases} \dots\dots\dots(6)$$

Positive value of Q indicates increasing trend while negative value of Q indicates decreasing trend. Q value indicates the steepness of trend. Sen's slope estimator has been widely used for calculating the magnitude of trend in hydro meteorological time series (Yue & Hashino, 2003)

3. Results and discussion

3.1.1 Trend of temperature in North Eastern Transition Zone (NETZ) during 1979-2019

North Eastern Transition Zone consists of Bidar and Gulbarga districts (Map 1) with 7 talukas. The total geographical area of the region is about 0.87Mha. The annual rainfall in this region varies from 700 to 890 mm. Bidar and Gulbarga have highest maximum temperature with 33°C (Table 2). The mean minimum and maximum temperature was highest in month of May with 25.60°C and 40.13°C, respectively (Table 3). Bidar receives maximum rainfall with 847 mm. The minimum temperature recorded in Gulbarga is 16.36°C. The results reveal that, monthly mean minimum temperature (MT_{min}) of August is increasing significantly with a magnitude of 0.012°C for the total forty years period from 1979 to 2019 (Table 4). The maximum temperature

has increased significantly in January, August, November and December with a magnitude of 0.030°C, 0.019°C, 0.045°C and 0.045°C, respectively. The seasonal significant trends are detected for maximum temperature during North east monsoon, Annual with magnitude of 0.035 and 0.018°C respectively.

Table 2: District wise variation of climatic variables of North Eastern Transition Zone 1979-2019

Districts	Maximum Temperature			Minimum Temperature			Rainfall		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Bidar	33.41	4.06	12.16	20.46	3.77	18.44	847.41	209.75	24.75
Gulbarga	33.44	3.89	11.64	20.88	3.41	16.36	724.56	153.76	21.22

Table 3: Monthly mean maximum and minimum temperature of North Eastern Transition Zone, 1979-2019

Month	Minimum Temperature				Maximum Temperature			
	Min T	Max T	Mean	SD	Min T	Max T	Mean	SD
Jan	12.82	17.34	15.57	1.03	27.76	32.17	30.50	0.89
Feb	15.62	19.90	17.76	0.99	31.66	35.79	33.43	0.94
Mar	19.79	23.09	21.15	0.68	34.74	38.69	36.93	1.07
April	22.27	26.50	24.24	0.72	37.20	41.87	39.46	0.96
May	23.50	26.92	25.60	0.77	35.70	41.93	40.13	1.28
June	22.39	24.91	23.68	0.63	31.33	37.65	35.05	1.46
July	21.74	23.78	22.53	0.41	29.19	34.65	31.59	0.99
Aug	21.30	23.05	22.00	0.32	29.44	32.52	30.61	0.67
Sep	21.41	22.77	21.89	0.31	29.55	33.04	31.35	0.85
Oct	19.39	21.65	20.55	0.57	29.96	34.22	31.89	1.05
Nov	14.99	20.34	17.70	1.25	28.98	32.63	30.72	0.87
Dec	13.39	18.64	15.33	1.12	28.00	32.69	29.79	1.02

Table 4 : Mann-Kendall test results of minimum and maximum temperatures of NETZ, 1979-2019

Month/Season	Minimum Temperature				Maximum temperature			
	T	S	p	β	T	S	P	B
January	-0.25	-206	0.021	-0.029**	0.30	252	0.005	0.030*
February	-0.11	-96	0.286	-0.015	0.18	150	0.094	0.023
March	-0.04	-38	0.678	0.005	0.15	125	0.164	0.020
April	0.02	16	0.866	0.001	0.07	58	0.522	0.011
May	0.16	138	0.124	0.018	0.07	58	0.522	0.001
June	0.11	94	0.296	0.009	0.01	8	0.937	0.003
July	0.20	166	0.064	0.011	0.00	2	0.991	0.000
August	0.33	276	0.002	0.012*	0.27	226	0.011	0.019*
September	0.05	48	0.598	0.002	-0.03	-28	0.762	0.003
October	0.01	10	0.919	0.001	0.09	78	0.387	0.014
November	0.02	16	0.866	0.004	0.42	350	<0.0001	0.045*
December	-0.04	-38	0.678	-0.007	0.37	310	0.001	0.045*
Winter	-0.19	-156	0.082	-0.021	0.27	224	0.012	0.024*
Summer	0.05	48	0.598	0.005	0.13	114	0.204	0.014
SWM	0.20	164	0.067	0.008	0.06	54	0.552	0.004
NEM	0.10	-4	0.973	0.000	0.36	296	0.001	0.035*
Annual	0.03	28	0.762	0.002	0.39	326	0.000	0.018*

Note : T indicates Kendall's rank correlation coefficient, S indicates Kendall score, p indicates Level of significance, β indicates Sen's slope; *,** &*** indicates 1%, 5% and 10% level of significance, respectively

3.1.2 Trend in temperature of North Eastern Dry Zone (NEDZ) during 1979-2019

North Eastern Dry Zone consists of three districts Gulbarga, Yadgir and Raichur (Map 2) with 11 talukas. The geographical area of this zone is 1.76 Mha The highest mean minimum temperature (25.48°C) and mean maximum temperature (37.07°C) was observed in May and March,

respectively (Table 5). The annual rainfall varies from 633 to 780 mm. All the three districts have highest maximum temperature (Table 6) with 33 °C. Gulbarga receives maximum rainfall with 724 mm. The minimum temperature was noticed in Yadgir with 21.11°C. The results reveal that, the mean minimum temperature of August has significantly increased (Table 7) with a magnitude of 0.010°C and has decreased in winter with magnitude of -0.022°C for the study period 1979 to 2019. The mean monthly maximum temperature significantly increased in January, August and November with magnitude of slope of 0.036, 0.023 and 0.041°C, respectively. The analysis of seasonal temperature trends revealed that warming trends were more pronounced in Winter and North east monsoon. The average annual warming for the last forty years was calculated to be 0.017°C.

Table 5: District wise variation in climatic variables of North Eastern Dry Zone, 1979-2019

Districts	Maximum Temperature			Minimum Temperature			Rainfall		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Gulbarga	33.44	3.89	11.64	20.88	3.41	16.36	724.56	153.76	21.22
Yadgir	33.48	3.82	11.40	21.11	3.29	15.61	678.70	142.20	20.95
Raichur	33.37	3.68	11.03	21.14	3.14	14.85	608.03	144.18	23.71

Note: SD is Standard Deviation; CV is Coefficient of Variation

Table 6: Monthly maximum and minimum temperature of North Eastern Dry Zone 1979-2019

Month	Minimum Temperature				Maximum temperature			
	Min T	Max T	Mean	SD	Min T	Max T	Mean	SD
Jan	13.58	17.77	16.24	0.96	29.71	33.73	31.75	0.77
Feb	16.18	20.51	18.44	1.00	31.92	35.67	33.68	0.86
Mar	20.51	23.57	21.72	0.71	34.77	38.63	37.07	0.98
April	22.38	26.67	24.54	0.72	37.36	41.72	39.31	0.92
May	23.65	26.84	25.48	0.76	35.66	41.59	39.63	1.24
June	22.64	24.92	23.63	0.55	31.89	37.22	34.74	1.28
July	22.08	23.72	22.65	0.38	29.50	34.69	31.75	0.96
Aug	21.52	23.16	22.15	0.33	29.71	32.90	30.86	0.65
Sep	21.38	22.82	22.02	0.33	29.59	32.96	31.46	0.87
Oct	19.66	21.98	21.02	0.56	30.00	33.90	31.80	0.99
Nov	16.23	20.76	18.44	1.13	29.06	32.52	30.69	0.81
Dec	14.44	19.02	16.15	1.02	28.19	32.65	29.87	0.94

Table 7: Mann-Kendall test results of minimum and maximum temperatures of NEDZ, 1979-2019

Month/season	Minimum Temperature				Maximum temperature			
	T	S	p	β	T	S	p	B
January	-0.22	-182	0.042	-0.025	0.44	364	<0.0001	0.036*
February	-0.13	-112	0.212	-0.019	0.15	124	0.160	0.017
March	-0.03	-28	0.762	-0.003	0.16	132	0.141	0.019
April	-0.02	-24	0.796	-0.001	0.06	52	0.567	0.008
May	0.13	108	0.229	0.012	0.03	30	0.745	0.005
June	0.15	102	0.132	0.012	0.01	8	0.937	0.002
July	0.2	164	0.067	0.008	0.06	52	0.567	0.006
August	0.29	242	0.007	0.010*	0.3	248	0.006	0.023*
September	0.04	34	0.711	0.001	-0.03	-26	0.779	-0.003
October	0.01	10	0.919	0.001	0.09	80	0.375	0.013
November	0.01	8	0.937	0.001	0.4	332	0.000	0.041*
December	-0.1	-82	0.363	-0.014	0.2	286	0.750	0.041
Winter	-0.24	-202	0.024	-0.022**	0.3	250	0.005	0.026*
Summer	0.04	34	0.711	0.003	0.13	114	0.204	0.012
SWM	0.18	154	0.086	0.007	0.11	92	0.307	0.008

<i>NEM</i>	-0.04	-36	0.694	-0.004	0.36	302	0.001	0.033*
<i>Annual</i>	-0.05	-42	0.645	-0.002	0.39	322	0.000	0.017*

Note : T indicates Kendall's rank correlation coefficient, S indicates Kendall score, p indicates Level of significance, β indicates Sen's slope; *,** &*** indicates 1%,5% and 10% level of significance, respectively

3.1. 3 Trend of temperature in Northern Dry Zone (NDZ) during 1979-2019

Northern Dry Zone consists of seven districts (Map 3) Koppal, Bagalkot, Bijapur, Davangere, Bellary, Belagum and Gadag with 18 talukas with area of 5.04Mha. The annual rainfall ranges from 500 mm to 625 mm. The monthly mean maximum temperature is highest for Bagalkot district with 32.42 °C (Table 8). The highest mean minimum and maximum temperatures were observed during May (23.51°C) and April (36.78°C), respectively. Belagum receives maximum rainfall with 935 mm, while minimum temperature was noticed in Davangere with 19.13°C. The minimum temperature didn't show any trend during the study period of 1979 to 2019. The result revealed a marked increase in the maximum temperature over time during the study period. The mean maximum temperature of the months of January, February, March, August, November and December showed significant increase during period 1979 to 2019 (Table 9). The magnitude of trend observed in November & December was 0.031°C for the study period of 1979-2019. The seasonal maximum temperature (Tmax) increased significantly in winter (0.026°C) and North East monsoon (0.023°C) for the whole of the study period 1979-2019 as shown in Table 10.

Table 8: District wise variations in climatic variables of Northern Dry Zone 1979-2019

Districts	Max temp			Min temp			Rainfall		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Koppal	31.62	3.19	9.79	20.54	2.81	13.7	587.38	149.13	25.38
Bagalakot	32.42	3.22	9.94	20.57	2.88	14.01	565.03	148.98	26.36
Bijapur	26.72	3.61	13.51	20.38	3.22	15.83	583.38	130.44	22.36
Davanagere	30.28	2.81	9.3	19.13	2.95	11.99	663.92	153.18	23.07
Bellary	32.02	3.12	9.77	20.28	2.72	13.45	562.1	127.55	22.69
Belagum	31.8	2.86	9	20.67	2.71	13.13	935.89	237.56	25.38
Gadag.	31.86	3.06	9.6	20.2	2.69	13.31	628.5	212.8	33.85

Table 9: Monthly mean maximum and minimum temperature of Northern Dry Zone, 1979-2019

Month	Minimum Temperature				Maximum Temperature			
	Min T	Max T	Mean	SD	Min T	Max T	Mean	SD
Jan	14.18	17.58	16.06	0.72	29.05	32.22	30.77	0.63
Feb	15.28	19.53	17.64	0.88	31.69	34.25	33.00	0.68
Mar	19.50	22.06	20.57	0.60	33.65	36.82	35.49	0.71
April	21.13	24.28	22.89	0.60	35.42	38.63	36.78	0.71
May	22.59	24.73	23.51	0.52	33.50	37.41	36.02	0.93
June	21.72	23.29	22.43	0.42	29.83	33.07	31.26	0.94
July	21.35	22.48	21.84	0.31	27.41	31.01	29.10	0.69
Aug	20.89	22.29	21.49	0.32	27.64	30.62	28.76	0.59
Sep	20.61	21.97	21.21	0.30	28.74	31.15	29.86	0.67
Oct	19.46	21.36	20.62	0.46	29.21	32.44	30.75	0.77
Nov	16.50	20.61	18.47	1.02	29.21	31.76	30.35	0.62
Dec	14.80	18.83	16.32	0.91	28.52	31.99	29.96	0.72

Table 10: Mann-Kendall test results for minimum and maximum temperatures of NDZ, 1979-2019

Month/Season	Minimum Temperature				Maximum temperature			
	τ	S	p	β	τ	S	p	B

January	-0.22	-182	0.042	-0.018**	0.38	316	0.000	0.024*
February	-0.09	-74	0.412	-0.011	0.29	242	0.007	0.027*
March	-0.01	-10	0.919	-0.001	0.22	182	0.042	0.018**
April	0.05	42	0.645	0.005	0.08	66	0.465	0.010
May	0.09	74	0.412	0.006	-0.03	-30	0.745	-0.003
June	0.10	86	0.34	0.004	0.02	18	0.849	0.003
July	0.18	152	0.09	0.008***	0.05	48	0.598	0.005
August	0.26	206	0.017	0.009*	0.42	348	<0.0001	0.023*
September	0.05	44	0.629	0.002	0.03	30	0.745	0.003
October	0.01	10	0.919	0.001	0.09	78	0.387	0.010
November	0.01	14	0.884	0.002	0.39	320	0.000	0.031*
December	-0.05	-44	0.629	0.002	0.35	290	0.001	0.031*
Winter	-0.20	-168	0.061	-0.016***	0.4	332	0.000	0.026*
Summer	0.06	54	0.552	0.00	0.07	58	0.522	0.005
SWM	0.18	150	0.094	0.004***	0.12	98	0.276	0.011
NEM	-0.01	-14	0.884	-0.001	0.31	254	0.004	0.023*
Annual	0.00	2	0.991	0.000	0.43	360	<0.0001	0.014*

Note: τ indicates Kendall's rank correlation coefficient, S indicates Kendall score, p indicates level of significance, β indicates Sen's slope; *, ** & *** indicates 1%, 5% and 10% level of significance, respectively.

3.1. 4 Trend in temperature of Central Dry Zone (CDZ) during 1979-2019

Central Dry zone consists of three districts (Map 4) Chitradurga, Davanagere and Tumkur with 17 taluks. Total geographical area of this zone is 1.98 Mha. The annual rainfall received in this zone ranges from 400mm to 620 mm. Chitradurga has highest maximum temperature (Table 11) with 31.20°C. The lowest mean minimum temperature and highest annual rainfall was noticed in Davanagere with 19.13 °C and 663 mm, respectively. The highest mean minimum temperature was noticed in May with 21.94°C while highest mean maximum temperature was noticed in April with 34.45°C (Table 12). The average monthly minimum temperature (Table 13) of the months of June, July, August, September, October increased significantly with magnitude of 0.010, 0.013, 0.015, 0.010 and 0.012°C, respectively. The highest magnitude of slope was recorded for the mean temperature of the month of August with 0.015°C. While the mean maximum temperature of the months of January, February, July, August and November recorded significant increase which has replicated for the temperatures of winter, South west monsoon and north east monsoon. The trend of annual mean maximum temperature increased with magnitude of 0.01°C for the study period 1979 to 2019.

Table 11 : District wise variation of climatic variables of Central Dry zone 1979-2019

Districts	Maximum temperature			Minimum Temperature			Rainfall		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Chitradurga	31.20	3.11	9.96	19.48	2.52	12.96	542.81	129.41	23.84
Davanagere	30.28	2.81	9.30	19.13	2.95	11.99	663.92	153.18	23.07
Tumakuru	30.40	2.88	9.47	19.17	2.38	12.41	654.62	141.98	21.68

Table 12: Monthly mean maximum and mean minimum temperature of Central Dry Zone, 1979-2019

Month	Minimum Temperature				Maximum temperature			
	Min T	Max T	Mean	SD	Min T	Max T	Mean	SD
Jan	13.88	17.10	15.43	0.82	27.68	30.18	28.99	0.52
Feb	14.50	18.92	17.06	0.89	29.64	32.32	31.28	0.66
Mar	18.48	20.99	19.61	0.58	31.21	35.03	33.59	0.74

April	20.21	23.11	21.67	0.55	33.05	36.62	34.45	0.83
May	21.24	23.29	21.94	0.46	30.21	34.87	33.41	0.96
June	20.31	22.12	21.01	0.42	28.15	31.23	29.52	0.84
July	20.01	21.17	20.52	0.32	26.91	29.48	28.10	0.59
Aug	19.69	21.22	20.28	0.34	26.94	29.47	27.82	0.51
Sep	19.35	20.83	20.06	0.33	27.58	30.24	28.79	0.63
Oct	18.87	20.51	19.66	0.42	27.92	30.27	28.92	0.60
Nov	16.25	19.72	17.90	0.81	27.13	30.25	28.20	0.62
Dec	14.55	18.55	15.92	0.89	26.65	29.13	27.96	0.64

Table 13: Mann-Kendall test results of minimum and maximum temperatures of CDZ, 1979-2019

CDZ Month/Season	Minimum Temperature				Maximum temperature			
	τ	S	p	β	τ	S	P	B
January	-0.07	-64	0.479	-0.009	0.36	296	0.001	0.032*
February	-0.10	-82	0.363	-0.011	0.22	182	0.042	0.020**
March	0.04	38	0.678	0.003	0.15	128	0.154	0.014
April	0.13	111	0.217	0.008	0.00	0	1.000	0.000
May	0.11	94	0.296	0.008	-0.17	-142	0.113	-0.018
June	0.19	160	0.074	0.010***	0.09	78	0.387	0.009
July	0.32	262	0.003	0.013*	0.19	158	0.078	0.013***
August	0.36	298	0.001	0.015*	0.30	246	0.006	0.018*
September	0.26	214	0.017	0.010*	0.06	54	0.552	0.005
October	0.18	152	0.090	0.012***	0.14	122	0.174	0.011
November	0.09	80	0.375	0.011	0.24	198	0.027	0.017**
December	0.07	64	0.479	0.009	0.17	144	0.108	0.016
Winter	-0.10	-82	0.363	-0.011	0.35	292	0.001	0.021*
Summer	0.12	98	0.276	0.007	-0.03	-26	0.779	-0.003
SWM	0.31	254	0.004	0.012*	0.19	160	0.074	0.011***
NEM	0.09	80	0.375	0.007	0.27	224	0.012	0.015*
Annual	0.17	138	0.124	0.006	0.26	210	0.019	0.010*

Note: τ indicates Kendall's rank correlation coefficient, S indicates Kendall score, p indicates level of significance, β indicates Sen's slope; *, ** & *** indicates 1%, 5% and 10% level of significance, respectively.

3.1.5 Trend of temperature in Eastern Dry zone (EDZ) during 1979-2019

Eastern Dry Zone consists of five districts (Map 5) Bengaluru, Tumkur, Ramanagar, Kolar and Chikballapur with 24 taluks. The geographical area of this zone is 1.80 Mha. The annual rainfall ranges from 750 to 810 mm. Kolar has highest maximum temperature with 31.53°C (Table 14). The lowest minimum temperature and rainfall was noticed in Ramanagar with 19.66°C and 832 mm, respectively. The highest mean minimum temperature was noticed (Table 15) in the month of may (22.63°C) whereas the highest mean maximum temperature was noticed in April (36°C). The significant trends are detected for minimum temperature (Table 16) of March, June, July, August, September and October with magnitude of 0.012, 0.010, 0.015, 0.018, 0.016 and 0.017°C, respectively for the study period 1979 to 2019. The magnitude of average monthly minimum temperature of August was recorded to be highest with 0.018°C. The change in minimum temperature was recorded in summer, south west monsoon, north east monsoon and annual. The monthly mean maximum temperature has increased significantly in

the months of January, August and December with magnitude of 0.021, 0.018, and 0.010°C, respectively.

Table 14: District wise variation in climatic variables of Eastern Dry zone, 1979-2019

District	Maximum temperature			Minimum Temperature			Rainfall		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Bangalore	30.75	2.90	9.45	19.66	2.37	12.08	787.53	208.21	26.43
Tumakuru,	30.40	2.88	9.47	19.17	2.38	12.41	654.62	141.98	21.68
Ramanagara,	30.75	2.90	9.45	20.10	2.26	11.24	832.71	188.21	22.60
Kolar	31.53	3.01	9.56	20.42	2.52	12.37	771.15	197.42	25.60
chikballapura.	31.29	3.08	9.86	20.19	2.61	12.96	646.37	166.18	25.710

Table 15: Monthly mean maximum and minimum temperature of Eastern Dry Zone, 1979-2019

Month	Minimum Temperature				Maximum temperature			
	Min T	Max T	Mean	SD	Min T	Max T	Mean	SD
Jan	14.21	17.49	15.91	0.79	27.56	30.58	29.31	0.60
Feb	15.27	19.41	17.47	0.90	29.86	33.06	31.96	0.75
Mar	19.87	20.82	20.12	0.22	32.12	35.99	34.65	0.81
April	20.95	23.95	22.36	0.56	34.39	38.11	36.00	0.85
May	21.85	23.85	22.63	0.43	32.08	37.01	35.42	1.01
June	20.96	22.76	21.63	0.42	30.21	33.45	31.61	0.89
July	20.51	21.82	21.10	0.35	28.04	31.01	29.38	0.63
Aug	20.04	21.48	20.82	0.33	28.77	31.13	29.56	0.51
Sep	19.99	21.39	20.66	0.33	28.76	31.51	30.14	0.71
Oct	19.35	20.80	20.16	0.37	28.68	31.39	29.89	0.65
Nov	16.80	19.90	18.48	0.74	27.42	30.82	28.73	0.63
Dec	14.90	18.87	16.61	0.88	26.73	29.50	28.17	0.68

Table 16: Mann-Kendall test results of minimum and maximum temperatures of EDZ, 1979-2019

EDZ	Minimum Temperature				Maximum temperature			
	τ	S	p	β	τ	S	P	B
January	-0.02	-20	0.831	-0.003	0.29	242	0.007	0.021*
February	-0.06	-56	0.537	-0.009	0.15	128	0.154	0.015
March	0.69	568	<0.0001	0.012*	0.16	134	0.135	0.016
April	0.12	106	0.238	0.008	0.03	28	0.762	0.003
May	0.14	116	0.196	0.007	-0.14	-122	0.174	-0.014
June	0.24	200	0.025	0.010**	0.06	50	0.582	0.006
July	0.35	294	0.001	0.015*	0.12	104	0.247	0.009
August	0.44	362	<0.0001	0.018*	0.27	228	0.011	0.018*
September	0.46	380	<0.0001	0.016*	0.01	12	0.902	0.001
October	0.27	228	0.011	0.017*	0.12	104	0.247	0.012
November	0.17	144	0.108	0.016	0.26	101	0.143	0.019
December	0.15	124	0.167	0.016	0.26	218	0.015	0.010*
Winter	-0.02	-16	0.866	-0.001	0.27	224	0.012	0.011*
Summer	0.26	214	0.017	0.007*	0.01	10	0.919	0.000
SWM	0.44	366	<0.0001	0.014*	0.18	152	0.090	0.090
NEM	0.25	212	0.018	0.016*	0.24	204	0.023	0.016**
Annual	0.30	246	0.006	0.010*	0.29	244	0.006	0.011*

Note: τ indicates Kendall's rank correlation coefficient, S indicates Kendall score, p indicates level of significance, β indicates Sen's slope, *, ** & *** indicates 1%, 5% and 10% level of significance, respectively

3.1.6 Trend in temperature of Southern Dry zone (SDZ) during 1979-2019

Southern dry zone consists of Mysuru, Mandya, Chamarajanaga and Hassan (Map 6) with 18 taluks with area coverage of 1.56 Mha. The annual rainfall ranges from 650 to 760 mm. All the four districts have highest maximum temperature (Table 17) with 29 °C. Hassan receives maximum rainfall with 1030 mm. The lowest mean minimum temperature was noticed in Mysore with 18.82°C. The highest mean minimum temperature was noticed (Table 18) in May (21.17°C) and maximum temperature was noticed in March (33.31°C). It was observed that (Table 19) minimum temperature has increased significantly in April, June, July, August, September, October with magnitude of 0.013, 0.011, 0.015, 0.019, 0.014 and 0.016°C respectively during the period from 1969 to 2019. The maximum temperature increased significantly in January, February, August and November. The highest monthly magnitude was recorded in February with 0.025°C. The trend of minimum and maximum temperatures occurred in all seasons except summer. The magnitude of annual temperature trend was recorded with 0.013°C in this zone during forty years.

Table 17: District wise variation of climatic variables of Southern Dry zone 1979-2019

Districts	Maximum Temperature			Minimum Temperature			Rainfall		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Mysuru	29.3	2.42	8.25	18.82	1.99	10.57	798.21	177.02	22.17
Mandya,	29.57	2.7	9.15	18.48	2.18	11.8	800.69	178.09	22.24
Chamarajanaga	29.54	2.5	8.47	18.88	2.04	10.83	856.99	187.59	21.88
Hassan	29.24	2.58	8.83	18.66	2.03	10.92	1030.81	193.89	18.8

Table: 18: Monthly maximum and minimum temperature of Southern Dry Zone, 1979-2019

Month	Minimum Temperature				Maximum temperature				
	Min T	Max T	Mean	SD	Min T	Max T	Mean	SD	
Jan	14.11	16.99	15.49	0.74	27.89	30.03	28.96	0.48	
Feb	14.61	18.51	16.80	0.82	29.65	32.25	31.19	0.66	
Mar	17.86	20.35	19.01	0.54	31.14	34.78	33.31	0.69	
April	19.66	22.37	20.93	0.51	32.28	35.70	33.54	0.78	
May	20.46	22.37	21.17	0.44	29.41	33.85	32.43	0.93	
June	19.32	21.22	20.29	0.40	27.21	30.31	28.58	0.82	
July	19.33	20.41	19.85	0.32	26.74	29.24	27.92	0.57	
Aug	19.04	20.53	19.72	0.36	26.12	28.70	27.07	0.52	
Sep	18.80	20.35	19.58	0.34	27.05	29.68	28.20	0.59	
Oct	18.59	20.09	19.35	0.38	27.42	29.85	28.56	0.57	
Nov	16.42	19.60	18.01	0.68	27.25	30.20	28.17	0.60	
Dec	14.62	18.85	16.31	0.91	26.96	29.38	28.17	0.62	

Table 19: Mann-Kendall test results of minimum and maximum temperatures of SDZ, 1979-2019

SDZ	Minimum Temperature				Maximum temperature				
	Month/Season	τ	S	P	β	τ	S	p	β
January		0.03	32	0.728	0.003	0.40	330	0.000	0.022*
February		0.03	26	0.779	0.003	0.31	260	0.004	0.025*
March		0.17	146	0.103	0.011	0.19	160	0.074	0.017
April		0.23	194	0.030	0.013**	0.05	44	0.629	0.005
May		0.17	146	0.103	0.009	-0.14	-118	0.189	-0.015
June		0.23	196	0.029	0.011**	0.11	96	0.286	0.011
July		0.37	310	0.001	0.015*	0.19	160	0.074	0.013
August		0.45	374	<0.0001	0.019*	0.31	254	0.004	0.019*

September	0.36	299	0.001	0.014*	0.10	84	0.351	0.008
October	0.30	252	0.005	0.016*	0.17	142	0.113	0.013
November	0.20	166	0.064	0.016	0.26	21	0.016	0.018**
December	0.13	108	0.229	0.017	0.19	160	0.074	0.019
Winter	0.02	18	0.849	0.002	0.40	334	0.000	0.023*
Summer	0.17	144	0.108	0.009	0.00	2	0.991	0.000
SWM	0.42	344	0.000	0.016*	0.28	230	0.010	0.014**
NEM	0.26	216	0.016	0.014**	0.30	252	0.005	0.017*
Annual	0.31	258	0.004	0.013*	0.34	280	0.002	0.013*

Note : T indicates Kendell's rank correlation coefficient, S indicates Kendell score, p indicates Level of significance, β indicates Sen's slope; *, ** & *** indicates 1%, 5% and 10% level of significance, respectively

3.1. 7 Trend in temperature of Southern Transition Zone (STZ) during 1979-2019

The southern transition zone consists of (Map 7) Mysore, Hassan and Shimoga districts comprising of 11 taluks with area of 1.66 Mha. The annual rainfall ranges from 820 to 910 mm. Hassan receives maximum rainfall with 1030mm (Table 20). The highest mean minimum temperature noticed in May (21.74°C) and maximum temperature (Table 21) noticed in April (33.58°C). The lowest minimum temperature was noticed in Shimoga with 16.27°C. The analysis showed that the average minimum temperature of the months of April and July increased with same magnitude of 0.012°C (Table 22) during the period 1979 to 2019. The average monthly maximum temperature of the January, February, March, August, November and December increased significantly. The magnitude of noticed increase in average maximum temperature in February was 0.033°C. The seasonal temperature of winter, South west monsoon, North east monsoon recorded with magnitude of 0.030, 0.014 and 0.020°C. The annual minimum and maximum temperature increased with magnitude values of 0.008°C and 0.016°C, respectively.

Table 20: District wise variation of climatic variables of Southern Transition zone ,1979-2019

Districts	Maximum Temperature			Minimum Temperature			Rainfall		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Mysuru	29.30	2.42	8.25	18.82	1.99	10.57	798.21	177.02	22.17
Hassan	29.24	2.58	8.83	18.66	2.03	10.92	1030.81	193.89	18.80
Shimoga	28.64	2.02	7.93	16.27	1.22	9.56	987.22	187.54	19.00

Table: 21Monthly maximum and minimum temperature of Southern transition Zone, 1979-2019

Month	Minimum Temperature				Maximum temperature			
	Min T	Max T	Mean	SD	Min T	Max T	Mean	SD
Jan	14.57	17.66	15.93	0.77	28.95	31.15	30.00	0.50
Feb	14.96	18.24	16.74	0.74	30.22	32.53	31.44	0.66
Mar	18.33	20.71	19.41	0.54	31.44	34.54	33.06	0.59
April	20.11	22.74	21.30	0.55	32.15	35.56	33.58	0.66
May	20.90	23.20	21.74	0.48	29.80	33.61	32.43	0.86
June	19.73	21.66	20.80	0.43	26.91	29.78	28.24	0.82
July	19.57	21.07	20.37	0.34	25.50	27.94	26.70	0.54
Aug	19.48	21.29	20.24	0.40	25.38	28.23	26.59	0.56
Sep	19.10	20.83	20.08	0.38	27.08	29.41	28.00	0.54
Oct	19.13	20.77	19.86	0.42	27.48	30.42	29.05	0.63
Nov	16.93	20.37	18.46	0.76	28.32	31.03	29.29	0.60

Dec	15.08	19.37	16.61	0.93	28.13	30.78	29.37	0.59
-----	-------	-------	-------	------	-------	-------	-------	------

Table 22: Mann-Kendall test results of minimum and maximum temperatures of STZ, 1979-2019

STZ Month/season	Minimum Temperature				Maximum temperature			
	T	S	P	β	T	S	p	β
January	-0.05	-46	0.613	-0.006	0.49	402	<0.0001	0.027*
February	-0.03	-32	0.728	-0.003	0.41	342	0.000	0.033*
March	0.10	88	0.328	0.006	0.33	274	0.002	0.022*
April	0.21	176	0.049	0.012**	0.11	94	0.296	0.009
May	0.10	86	0.340	0.006	0.10	84	0.194	0.001
June	0.14	116	0.196	0.008	-0.10	-88	0.328	0.028
July	0.26	218	0.015	0.012*	0.12	102	0.257	0.008
August	0.31	258	0.004	0.016*	0.36	302	0.001	0.022*
September	0.19	162	0.071	0.010	0.12	98	0.276	0.007
October	0.20	170	0.058	0.012	0.16	134	0.135	0.013
November	0.12	106	0.238	0.013	0.34	282	0.002	0.025*
December	0.09	76	0.400	0.011	0.28	232	0.009	0.021*
Winter	-0.05	-48	0.598	-0.006	0.52	426	<0.0001	0.030*
Summer	0.18	150	0.094	0.009***	0.10	88	0.328	0.006
SWM	0.26	220	0.014	0.011*	0.25	208	0.020	0.014**
NEM	0.16	136	0.129	0.011	0.36	296	0.001	0.020*
Annual	0.20	170	0.058	0.008***	0.46	382	<0.0001	0.016*

Note : T indicates Kendell's rank correlation coefficient, S indicates Kendell score, p indicates Level of significance, β indicates Sen's slope *, ** & *** indicates 1%, 5% and 10% significance respectively

3.1.8 Trend in temperature of North Transition Zone (NTZ) during 1979-2019

The zone consists (Map 8) of Belagavi, Dharwad and Haveri districts with 14 taluks. It has an area of about 1.13Mha. The annual rainfall is > 850mm. All the three districts receives highest maximum temperature with 31°C (Table 23). The highest mean minimum temperature is noticed (Table 24) in the month of May (23.54°C) and maximum temperature is noticed in April (35.96°C). Belagum receives maximum rainfall with 935 mm. The lowest minimum temperature was noticed in Haveri with 19.93°C. The results (Table 25) revealed that, minimum temperature has decreased in January but increased in South west monsoon with magnitude of -0.022 and 0.006°C, respectively. The maximum temperature increased significantly in January, February, March, April, August, November and December during 1969 to 2019. The highest magnitude of maximum temperature recorded in 0.031° C in February. The seasonal maximum temperature increased in winter, South west monsoon, North east monsoon with magnitude of 0.026, 0.012 and 0.022°C, respectively. The annual maximum temperature increased by 0.016°C in NTZ during forty years.

Table 23: District wise variation of climatic variables of Northern Transition Zone 1979-2019

Districts	Maximum Temperature			Minimum Temperature			Rainfall		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Belagum	31.8	2.86	9	20.67	2.71	13.13	935.89	237.56	25.38
Dharwad	31.67	2.66	8.42	20.94	2.58	12.35	780.49	395.93	50.72
Haveri	31.32	2.91	9.3	19.93	2.57	12.94	859.85	260.52	30.29

Table 24: Monthly maximum and minimum temperature of Northern Transition Zone 1979-2019

Month	Minimum Temperature				Maximum temperature			
	Min T	Max T	Mean	SD	Min T	Max T	Mean	SD
Jan	14.56	17.90	16.42	0.81	29.38	32.41	31.07	0.59
Feb	15.30	19.44	17.72	0.87	31.28	33.95	32.75	0.69

Mar	19.45	21.92	20.53	0.67	33.40	36.00	34.78	0.64
April	21.11	23.90	22.78	0.61	34.69	37.47	35.96	0.61
May	22.82	24.77	23.54	0.49	32.82	36.58	35.28	0.80
June	21.85	23.47	22.62	0.39	29.25	32.27	30.63	0.88
July	21.58	22.66	22.08	0.29	26.96	30.29	28.50	0.64
Aug	21.18	22.58	21.79	0.32	27.23	30.08	28.29	0.62
Sep	20.89	22.22	21.46	0.32	28.59	30.85	29.57	0.61
Oct	19.88	21.83	21.06	0.46	29.42	32.59	30.89	0.77
Nov	16.97	21.16	19.08	1.02	29.82	32.24	30.98	0.61
Dec	15.47	19.29	17.00	0.89	29.37	32.45	30.62	0.65

Table 25: Mann-Kendall test results of minimum and maximum temperatures of NTZ 1979-2019

Month/season	Minimum Temperature				Maximum temperature			
	T	S	p	β	T	S	p	β
January	-0.23	-192	0.032	-0.022**	0.35	286	0.001	0.023*
February	-0.02	-22	0.814	-0.004	0.34	280	0.002	0.031*
March	0.01	12	0.902	0.001	0.24	196	0.029	0.022**
April	0.11	92	0.307	0.009	0.21	174	0.052	0.016**
May	0.05	46	0.613	0.003	0.05	40	0.661	0.003
June	0.08	72	0.425	0.004	0.02	12	0.902	0.003
July	0.15	130	0.147	0.006	0.05	40	0.661	0.004
August	0.12	8	0.12	0.000	0.46	378	<0.0001	0.025*
September	0.05	46	0.613	0.003	0.08	64	0.479	0.005
October	0.03	29	0.753	0.002	0.08	64	0.479	0.011
November	0.01	10	0.919	0.003	0.40	328	0.000	0.030*
December	-0.04	-36	0.694	-0.004	0.37	302	0.001	0.029*
Winter	-0.16	-138	0.124	-0.010	0.42	348	<0.0001	0.026*
Summer	0.08	70	0.438	0.005	0.18	146	0.103	0.011
SWM	0.18	148	0.099	0.006***	0.18	150	0.094	0.012***
NEM	0.00	6	0.955	0.000	0.33	274	0.002	0.022*
Annual	0.01	14	0.884	0.001	0.52	426	<0.0001	0.016*

Note : T indicates Kendell's rank correlation coefficient, S indicates Kendell score, p indicates Level of significance, β indicates Sen's slope *, ** & *** indicates 1%, 5% and 10% significance respectively

3.1.9 Trend of temperature in Hilly Zone (HZ) during 1979-2019

The hilly zone consists (Map 9) of Uttara Kannada, Chikmagalur, Kodagu and Belagum. The geographical area is 2.27 Mha. The annual rainfall received is 1,050 mm. The maximum temperature of Belagum was highest with 31.80°C (Table 26). Uttara Kannada receives maximum rainfall with 3994 mm. The mean minimum temperature was observed to be lowest of Chikmagalur with 16.90°C. The mean minimum temperature (Table 27) and maximum temperature was observed to be highest in may (20.43°C) and in April (33.86°C), respectively. The results of Mann Kendall analysis test (Table 28) revealed a marked decrease in the mean minimum and maximum temperature. The decrease in temperature was recorded in all months and seasons. The magnitude of monthly mean minimum temperature ranges from -0.023 to 0.038°C. The monthly mean maximum temperature decreased with magnitude ranging from -0.037 to -0.070°C. The annual maximum temperature recorded a decrease by -0.05°C in Hilly zone.

Table 26: District wise variation of climatic variables of Hilly zone 1979-2019

Maximum temperature	Minimum Temperature	Rainfall
---------------------	---------------------	----------

Districts	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Belagum	31.80	2.86	9.00	20.67	2.71	13.13	935.89	237.56	25.38
Chikmagaluru	26.11	2.55	9.78	16.90	1.50	8.93	1457.33	235.37	16.15
Kodagu	28.85	2.31	8.02	18.86	1.84	9.79	3429.51	647.68	18.88
Uttarakannada	31.06	2.59	8.35	20.41	2.42	11.86	3994.46	704.32	17.63

Table 27: Monthly maximum and minimum temperature of Hilly Zone, 1979-2019

Month	Minimum Temperature				Maximum temperature			
	Min T	Max T	Mean	SD	Min T	Max T	Mean	SD
Jan	15.00	17.92	16.34	0.67	27.20	29.70	28.52	0.68
Feb	15.88	18.79	17.18	0.65	28.29	31.52	29.58	0.80
Mar	17.80	19.72	18.77	0.55	28.79	32.92	30.76	1.00
April	19.04	21.38	20.12	0.59	29.41	33.86	31.25	1.11
May	19.38	22.04	20.43	0.62	28.52	33.02	30.60	1.18
June	18.66	20.83	19.77	0.53	25.88	29.69	27.79	0.91
July	18.55	20.39	19.44	0.47	24.99	28.33	26.76	0.75
Aug	18.55	20.15	19.35	0.44	25.17	28.74	26.69	0.71
Sep	18.32	20.11	19.25	0.47	26.15	29.28	27.59	0.77
Oct	17.98	19.95	19.08	0.50	26.99	29.88	28.18	0.79
Nov	16.86	19.93	18.10	0.65	26.77	29.48	28.19	0.66
Dec	15.76	18.56	16.84	0.69	26.83	29.40	28.12	0.68

Table 28: Mann-Kendall test results of minimum and maximum temperatures of HZ, 1979- 2019

Month/Season	Minimum Temperature				Maximum temperature			
	T	S	p	β	T	S	p	β
January	-0.35	-288	0.001	-0.032*	-0.75	-618	<0.0001	-0.053*
February	-0.41	-338	0.000	-0.030*	-0.68	-562	<0.0001	-0.056*
March	-0.56	-462	<0.0001	-0.035*	-0.7	-576	<0.0001	-0.070*
April	-0.57	-472	<0.0001	-0.038*	-0.66	-548	<0.0001	-0.074*
May	-0.65	-538	<0.0001	-0.041*	-0.68	-560	<0.0001	-0.083*
June	-0.61	-504	<0.0001	-0.036*	-0.48	-394	<0.0001	-0.053*
July	-0.64	-526	<0.0001	-0.031*	-0.48	-398	<0.0001	-0.042*
August	-0.52	-442	<0.0001	-0.029*	-0.37	-308	0.001	-0.037*
September	-0.53	-442	<0.0001	-0.031*	-0.46	-384	<0.0001	-0.046*
October	-0.52	-428	<0.0001	-0.031*	-0.55	-452	<0.0001	-0.052*
November	-0.30	-248	0.006	-0.027*	-0.56	-462	<0.0001	-0.044*
December	-0.26	-220	0.014	-0.023*	-0.68	-562	<0.0001	-0.049*
Winter	-0.41	-340	0.000	-0.030*	-0.78	-644	<0.0001	-0.054*
Summer	-0.64	-526	<0.0001	-0.039*	-0.74	-610	<0.0001	-0.076*
SWM	-0.60	-494	<0.0001	-0.031*	-0.53	-436	<0.0001	-0.043*
NEM	-0.46	-380	<0.0001	-0.029*	-0.64	-526	<0.0001	-0.049*
Annual	-0.66	-546	<0.0001	-0.032*	-0.79	-650	<0.0001	-0.055*

Note : T indicates Kendell's rank correlation coefficient, S indicates Kendell score, p indicates Level of significance, β indicates Sen's slope, *, ** & *** indicates 1%, 5% and 10% level of significance respectively

3. 1. 10 Trend of temperature in Coastal Zone (CZ) during 1979-2019

This zone consists two districts (Map 10) Uttara Kannada and Dakshina Kannada with 13 Taluks. The geographical area of this zone is 0.98 Mha. The annual rainfall ranges between 3300 to 3,500 mm. Uttara Kannada has highest mean maximum temperature with 31°C and also receives maximum rainfall with 3994 mm (Table 29). The mean minimum temperature and maximum temperature (Table 30) was observed to be highest in the month of may (22.62°C)

and in April (34.03°C). Dakshin Kannada was observed to have recorded lowest minimum temperature with 19.75°C. The results revealed that the magnitude of mean minimum temperature of July and August increased by 0.010 and 0.015°C, respectively (Table 31). In south west monsoon the mean minimum temperature increased by 0.01°C during 1979 to 2019. The maximum temperature during the same period increased significantly in January, February, March, August, November, and December with magnitude of 0.027, 0.038, 0.022, 0.024, 0.027, 0.024 and 0.032°C, respectively. The mean maximum temperature of South west monsoon and north east monsoon recorded an increase of 0.014 °C and 0.021°C, respectively. The annual maximum temperature of coastal zone increased with magnitude of 0.018°C.

Table 29: District wise variation of climatic variables of Coastal zone ,1979-2019

Districts	Maximum temperature			Minimum Temperature			Rainfall		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Uttara Kannada	31.06	2.59	8.35	20.41	2.42	11.86	3994	704.32	17.63
Dakshina Kannada	29.75	2.53	8.52	19.75	1.96	9.93	1997	348.57	17.45

Table 30 : Monthly maximum and minimum temperature of Coastal zone , 1979-2019

Month	Minimum Temperature				Maximum temperature			
	Min T	Max T	Mean	SD	Min T	Max T	Mean	SD
Jan	15.25	18.54	16.68	0.80	28.82	31.80	30.63	0.56
Feb	15.69	19.72	17.78	0.86	29.68	32.92	31.86	0.75
Mar	19.11	21.42	20.11	0.58	31.97	34.77	33.41	0.57
April	20.76	23.46	22.06	0.57	32.66	35.83	34.03	0.60
May	21.79	24.04	22.62	0.49	30.45	34.25	33.04	0.82
June	20.69	22.40	21.61	0.42	27.50	30.33	28.82	0.81
July	20.42	21.87	21.15	0.32	25.90	28.54	27.18	0.55
Aug	20.34	22.02	21.01	0.38	25.89	28.76	27.08	0.57
Sep	19.99	21.59	20.83	0.36	27.62	29.85	28.48	0.54
Oct	19.77	21.36	20.60	0.41	28.17	31.19	29.74	0.66
Nov	17.51	21.14	19.15	0.80	29.16	31.66	30.19	0.58
Dec	15.83	19.98	17.31	0.93	29.13	31.68	30.21	0.57

Table 31: Mann-Kendall test results of minimum and maximum temperatures of, CZ 1979 to 2019

CZ	Minimum Temperature				Maximum temperature			
	T	S	p	β	T	S	p	β
January	-0.14	-122	0.174	-0.016	0.46	384	<0.0001	0.027*
February	0.00	6	0.955	0.001	0.44	366	<0.0001	0.038*
March	0.09	78	0.387	0.002	0.33	276	0.002	0.022*
April	0.21	174	0.052	0.013	0.16	138	0.124	0.013
May	0.11	90	0.317	0.006	-0.04	-36	0.694	-0.004
June	0.12	98	0.276	0.006	0.08	68	0.452	0.010
July	0.23	192	0.032	0.010*	0.12	98	0.276	0.008
August	0.30	249	0.005	0.015*	0.41	340	0.000	0.024*
September	0.18	148	0.099	0.009	0.11	96	0.286	0.007
October	0.17	142	0.113	0.009	0.15	124	0.167	0.012
November	0.10	86	0.34	0.011	0.38	314	0.000	0.027*
December	0.05	48	0.598	0.008	0.36	300	0.001	0.024*
Winter	-0.07	-62	0.493	-0.010	0.52	432	<0.0001	0.032*
Summer	0.16	134	0.135	0.009	0.15	128	0.154	0.009

<i>SWM</i>	0.26	218	0.015	0.014*	0.27	222	0.013	0.014*
<i>NEM</i>	0.12	102	0.257	0.009	0.36	300	0.001	0.021*
<i>Annual</i>	0.14	116	0.196	0.005	0.52	426	<0.0001	0.018*

Note : T indicates Kendall's rank correlation coefficient, S indicates Kendall score, p indicates Level of significance, β indicates Sen's slope *,** & *** indicates 1%, 5% and 10% level of significance, respectively

Conclusion:

In general, Karnataka has warmed significantly between 1979 and 2019 with climate variability occurred between late 1990s and early 2000s. As a result, the south west monsoon has been decreased with more dispersion and slight change in the trend of the north east monsoon which ultimately effect the Kharif crop production compared to Rabi

Recommendations and suggestions for future scope of work

- Researchers should develop crop varieties that are insensitive to temperature changes.
- The scientist should develop packages of practices which will help mitigate adverse effect of fluctuations in climate parameters on crop productivity.
- There is a need for government programs to educate farmers and provide them with more localized information on climate forecasts, climate change and droughts.
- The implementation of meteorological departments in large number for better weather information which helps in improving the reliability of drought predictions.
- Satellite imagery is recommended for better land use and water use assessment at district level.

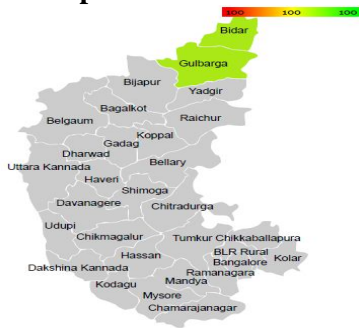
References

- Bonfils, S. (2012). Trend analysis of the mean annual temperature in Rwanda during the last fifty two years. *Journal of Environmental Protection*, 2012.
- Deb, S., & Sil, B. S. (2020). Trend analysis of climatic variables for the subtropical region of Assam and its neighbouring states in NE India.
- Dhorde, A. G., & Zarenistanak, M. (2013). Three-way approach to test data homogeneity: An analysis of temperature and precipitation series over southwestern Islamic Republic of Iran. *J. Indian Geophys. Union*, 17(3), 233-242.
- Gadedjisso-Tossou, A., Adjegan, K. I., & Kablan, A. K. M. (2021). Rainfall and Temperature Trend Analysis by Mann-Kendall Test and Significance for Rainfed Cereal Yields in Northern Togo. *Sci*, 3(1), 17.
- Mohamed, M. A. H., & El-Mahdy, M. E. S. (2021). Evaluation of climate change impact on extreme temperature variability in the Blue Nile Basin, Ethiopia. *Geoscientific Instrumentation, Methods and Data Systems*, 10(1), 45-54.
- Panda, A., & Sahu, N. (2019). Trend analysis of seasonal rainfall and temperature pattern in Kalahandi, Bolangir and Koraput districts of Odisha, India. *Atmospheric Science Letters*, 20(10), e932.
- Prabhakar, A. K., Singh, K. K., Lohani, A. K., & Chandniha, S. K. (2017). Long term rainfall variability assessment using modified Mann-Kendall test over Champua watershed, Odisha. *J. Agrometeorol*, 17(2), 288-289.
- Varadan, R. J., & Kumar, P. (2015). Mapping agricultural vulnerability of Tamil Nadu, India to climate change: a dynamic approach to take forward the vulnerability assessment methodology. *Climatic change*, 129(1), 159-181.

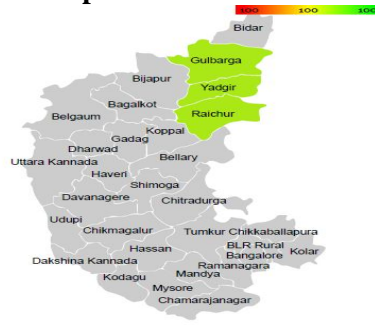
Waghaye, A. M., Rajwade, Y. A., Randhe, R. D., & Kumari, N. (2018). Trend analysis and change point detection of rainfall of Andhra Pradesh and Telangana, India.

Map showing different Agro Climatic Zones of Karnataka state

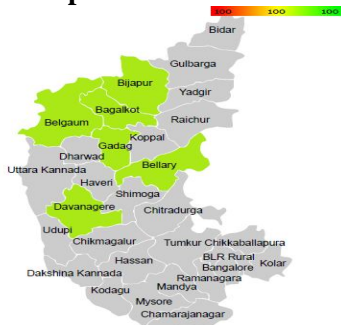
Map 1: ACZ-I -NETZ



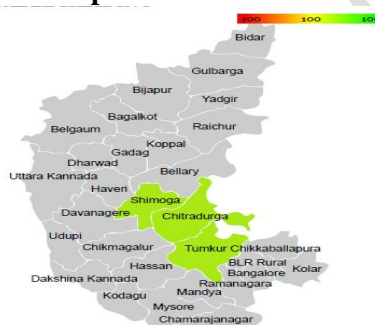
Map 2 : ACZ-II -NEDZ



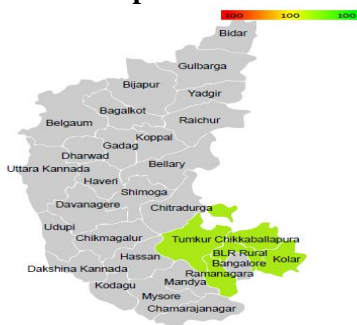
Map 3: ACZ-III -NDZ



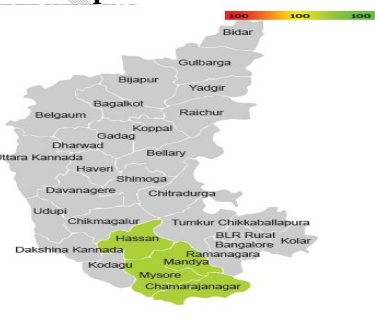
Map 4: ACZ-IV -CDZ



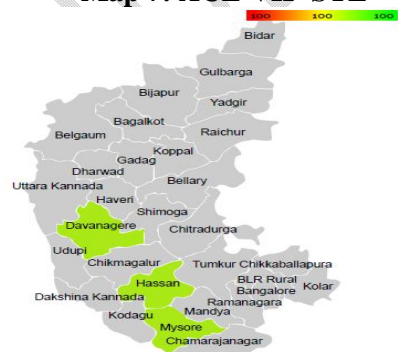
Map 5: ACZ-V -EDZ



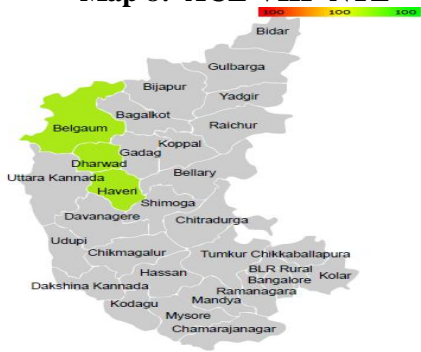
Map 6: ACZ-VI -SDZ



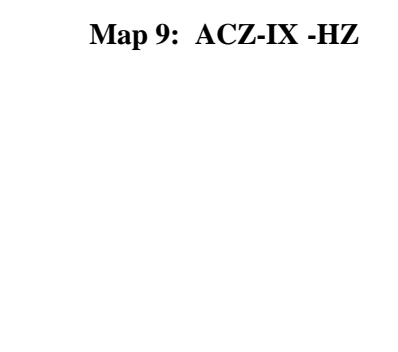
Map 7: ACZ-VII -STZ



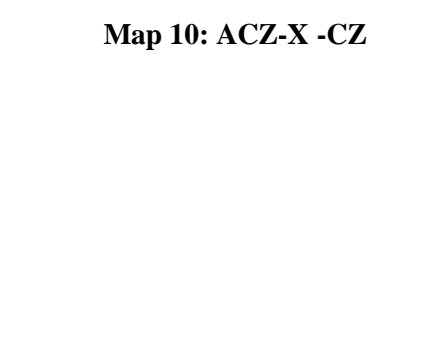
Map 8: ACZ-VIII- NTZ

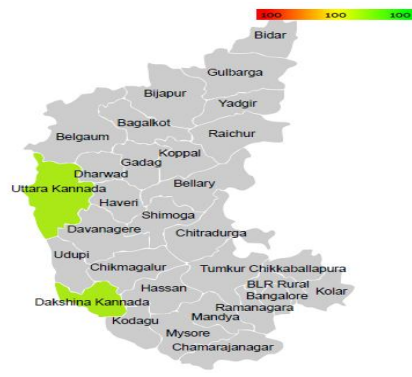
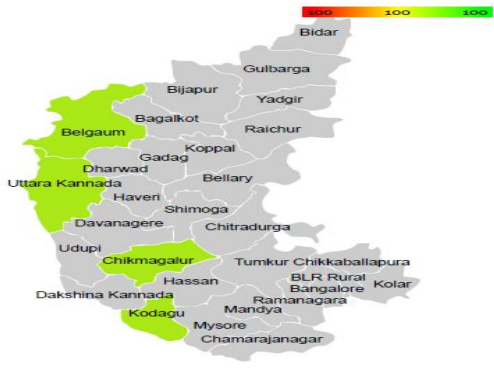


Map 9: ACZ-IX -HZ



Map 10: ACZ-X -CZ





UNDER PEER REVIEW