

## Original Research Article

# DETECTION OF CLIMATE CHANGE IN KARNATAKA STATE IN INDIA DURING THE PERIOD (1979-2019)

## ABSTRACT

This paper deals with study of exposure of Karnataka state to climate change for a period 1979-2019. The Mann Whitney Pettit's homogeneity test (MWP) was analysed for 240 data sets for monthly data of minimum (MTmin) and maximum temperature (MT max) across ten agro climatic zones) to estimate the year of structural break or year of shift in mean monthly temperature from one level to next higher level during the forty years of study period i.e., 1979-2019. About 77 data sets were identified to show year of structural break. The annual mean temperature recorded an upward shift in all the agro climatic zones of Karnataka except in hilly zone. The break year was chosen based on its frequent occurrence in data sets of minimum and maximum temperature. It is observed to be 1998 for North Eastern Transition Zone and is 1997, 1994, 1996, 1995, 1996, 1999, 1999, 1999 and 1997 for North Eastern Dry Zone, Northern Dry Zone, Central Dry Zone, Eastern Dry Zone, Southern Dry Zone, Southern Transition Zone, Northern Transition Zone, Hilly Zone and Coastal Zone respectively. Therefore, it is a evidential picture reflecting the increase in temperatures across the zones. Researchers should develop crop varieties that are insensitive to temperature changes and should develop packages of practices which will mitigate adverse effect of fluctuations in climate parameters on crop productivity.

**Key word:** Agro-climatic zones, Break year, Climate change, Mitigate, Shift, Temperature

## 1. INTRODUCTION

The emission of greenhouse gases disturb 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 METHODS**

### ***2.1 Study location***

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. There are five Agro Climatic Zones (ACZ) namely, ACZ-II, ACZ-III, ACZ-IV, ACZ-V, ACZ-VI with relatively low rainfall and more erratic distribution and are classified under Dry Zone. Similarly, along the eastern part of the Hill zones and to the west of the Dry zones there lies a region with relatively high rainfall with less erratic distribution and also a small portion of area in the north eastern part of the state were together identified as Transitional zones. This zone comprises three Agro Climatic Zones namely, ACZ-I, ACZ-VII, ACZ-VIII. The hill and coastal belts of Karnataka state are the two distinct Agro-climatic zones namely, ACZ-IX and ACZ-X and is together classified as Hill and Coastal Zone.

### ***2.2 Data and analysis***

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. 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. About 240 data sets are obtained for Mann Whitney test after excluding seasonal data. As per the requirement of the objective, necessary analytical tools were used to evaluate the data. Non parametric test were used in the study because they are very less affected by the presence of outlier and other form of non normality. The statistical method try to analyse the exposure concepts of climate change for Karnataka. The shift points or change year of temperature is identified through Mann Whitney Pettit’s homogeneity test.

### 2.3 Mann Whitney Pettit Method (MWP) homogeneity test

Mann Whitney Pettit Method is used to identify the sudden or abrupt change in climatologically trend (Pettitt 1979)

$$U_k = 2 \sum_{t=0}^n mt - k(n + 1) \dots \dots \dots (1)$$

Where  $M_i$  is the rank of the  $i^{th}$  observation when the values  $X_1, X_2, \dots, X_n$  in the series are arranged in the ascending order. Then the statistical change point (SCP) test statistic is defined as:

$$k = \max |U_k| \dots \dots \dots (2)$$

A change point occurs in the series at which  $U_k$  attains a maximum value of  $K$ . A time series  $(X_1, X_2, \dots, X_n)$  with length  $n$  is considered. Let  $t$  be taken as the time of the most expected change point. Two samples of  $(X_1, X_2, \dots, X_t)$  and  $(X_{t-1}, X_{t+2}, \dots, X_n)$  can be then obtained by dividing the time series at  $t$  time. The  $U_t$  index is derived in the following way

$$\text{Sign}(X_j - X_i) = 1 \text{ if } (X_j - X_i) > 0 \dots \dots \dots (3)$$

$$\text{Sign}(X_j - X_i) = 0 \text{ if } (X_j - X_i) = 0 \dots \dots \dots (4)$$

$$\text{Sign}(X_j - X_i) = -1 \text{ if } (X_j - X_i) < 0 \dots \dots \dots (5)$$

Plotting the  $U_t$  value against ‘ $t$ ’ in a time series, no change point will result in a continuously increasing value of  $U_t$ . Nevertheless, if there is a presence of change point, then  $U_t$  will increase up to the level of the change point and then it will begin to decrease. The main significant change point  $t$  is considered as the point where the value of  $U_t$  remains highest.

$$K_t = \max U_t \dots \dots \dots (6)$$

$$1 < t < T$$

The estimated significant probability  $P(t)$  for a change point (Pettit, 1979) is given as

$$P=1-\exp(-6k^2t/n^3-n^2)\dots\dots(7)$$

The change point becomes statistically significant at 't' time with the significant level when probability P(t) surpasses (1- $\alpha$ ).

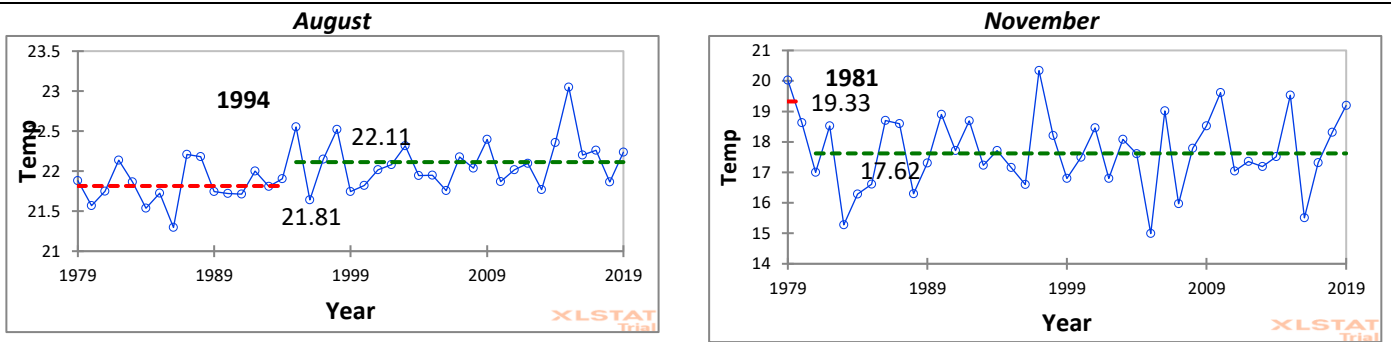
The null hypothesis states that there is no shift or displacement in mean monthly temperature (MT min or MT max) data and the alternate hypothesis states that a certain data may be distinguished as a change point and mean monthly temperature data set is significantly displaced at the break point (Gholami et al., 2022).

### 3.RESULTS AND DISCUSSION

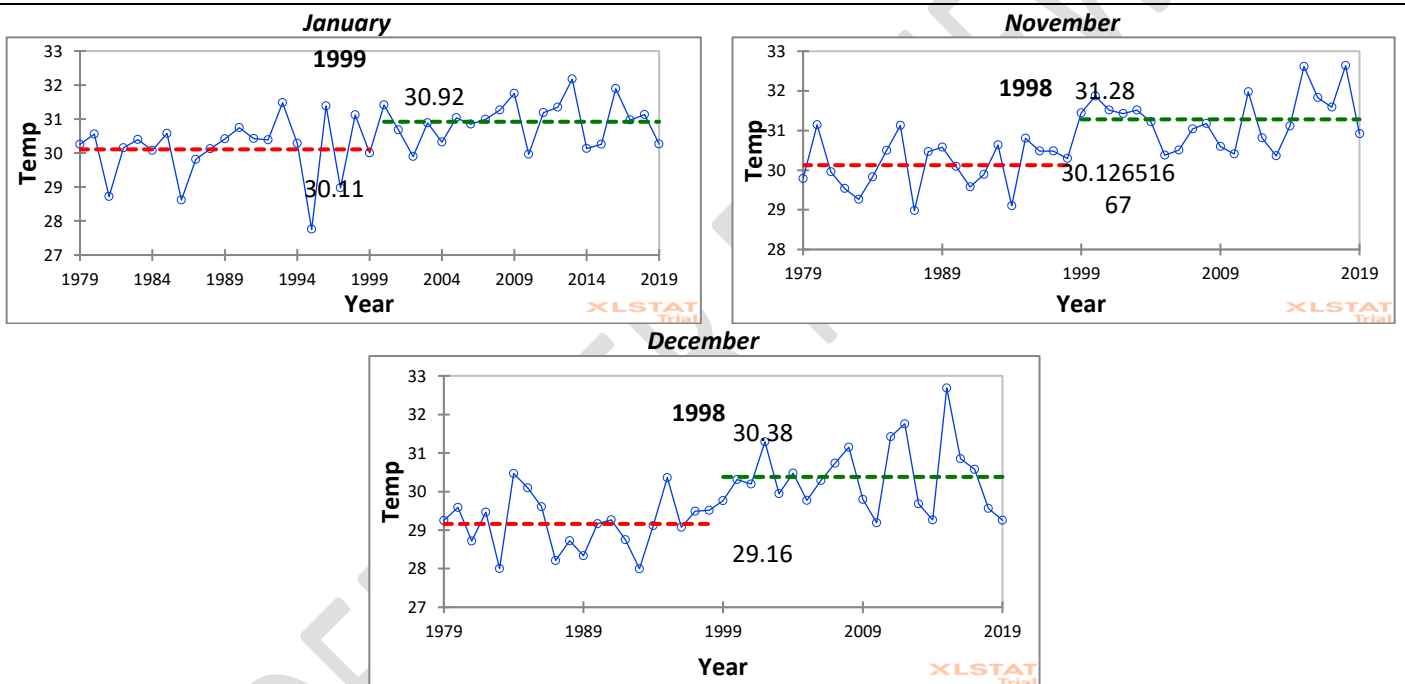
Prior to analyzing the impact of climate change on environment and hydrological aspects, it is necessary to determine homogeneity of climate data which has great importance in climate change monitoring, weather forecasting, drought monitoring. The Pettit's test is a non-parametric test that is used to identify the point at which the time series data takes a shift from one level to another. The break year is detected near the year when the estimated values exceed the critical value. The results obtained for ten agro climatic zones are presented in the form of figures in this section. A horizontal line in the figures is used to represent the critical value of test statistics at a 95 percent confidence level. If the estimated value is more than critical value, the null hypothesis of homogeneity cannot be rejected and it is considered as homogenous. Non homogeneity was found to vary for different months at different agro climatic zones.

#### 3.1 Shift in mean temperature in North Eastern Transition Zone during 1979-2019

There is an upward shift in mean minimum temperature of August from 21.81 to 22.11°C in 1994 which implies that temperature increased by 0.3 percent in that year (Figure 1). The mean minimum temperature of November shifted downwards in the year 1981 from 19.33 to 17.62°C. The mean maximum temperature of January has recorded a shift during the year 1999 from 30.11 to 30.92°C (Figure 2) while shift of mean temperature of November was 30.12 to 31.28°C. The mean temperature of December shifted from 29.16 to 30.38°C in 1998. The shift in annual mean temperature was observed between the year 1994 and 1998.



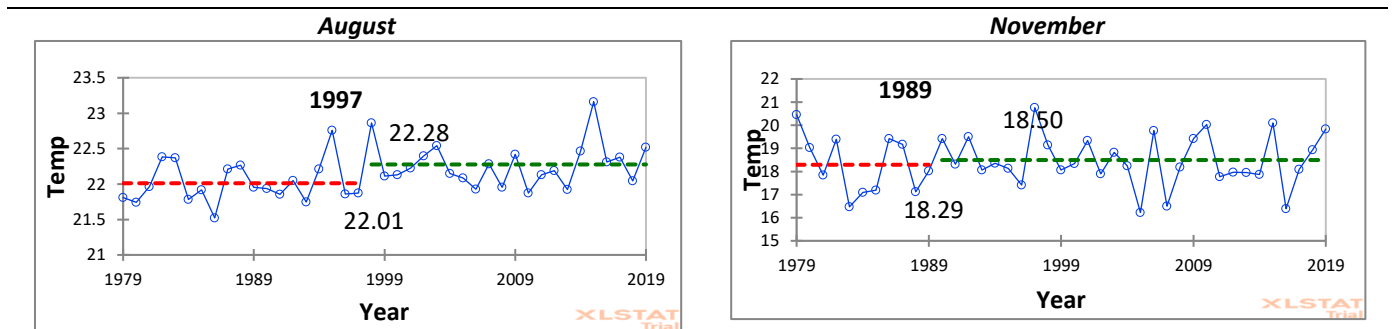
**Fig 1: Pettit's homogeneity shift in monthly mean minimum temperature of NETZ**



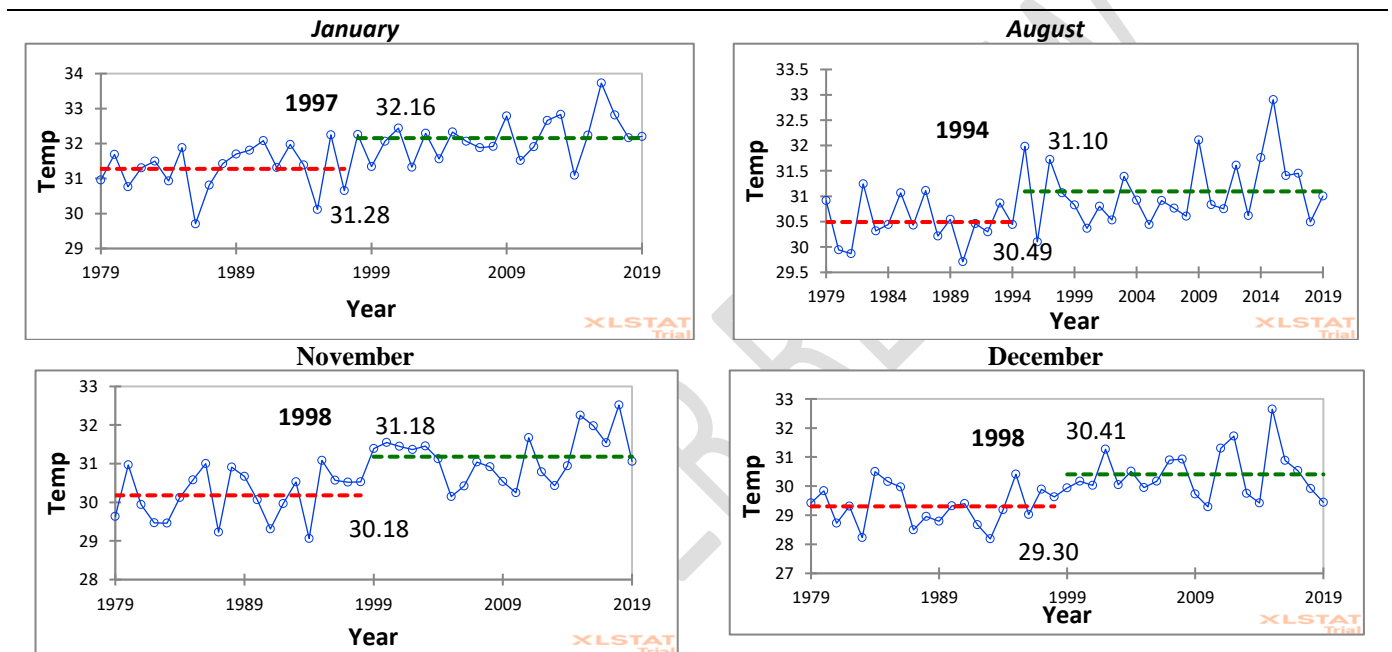
**Fig 2: Pettit's homogeneity shift in monthly mean maximum temperature of NETZ**

### 3.2 Shift in mean temperature in North eastern dry zone during 1979-2019

There is an upward shift in the year 1997 of mean minimum temperature of August from 22.01 to 22.28°C (Figure 3) while that of November was in year 1989 from 18.29 to 18.50°C. The mean maximum temperature of January month recorded a shift in the year 1997 from 31.28 to 32.16°C. The shift of temperature from 30.49 to 31.10°C occurred for the mean temperature of August month in the 1994. The maximum temperature of November month shifted from 30.18 to 31.18°C and of December month shifted from 29.30 to 30.41°C in the year 1998 (Figure 4). There is an upward shift of mean maximum temperatures that was observed to have taken place during the period 1994 to 1998 in the North Eastern Dry Zone of Karnataka.



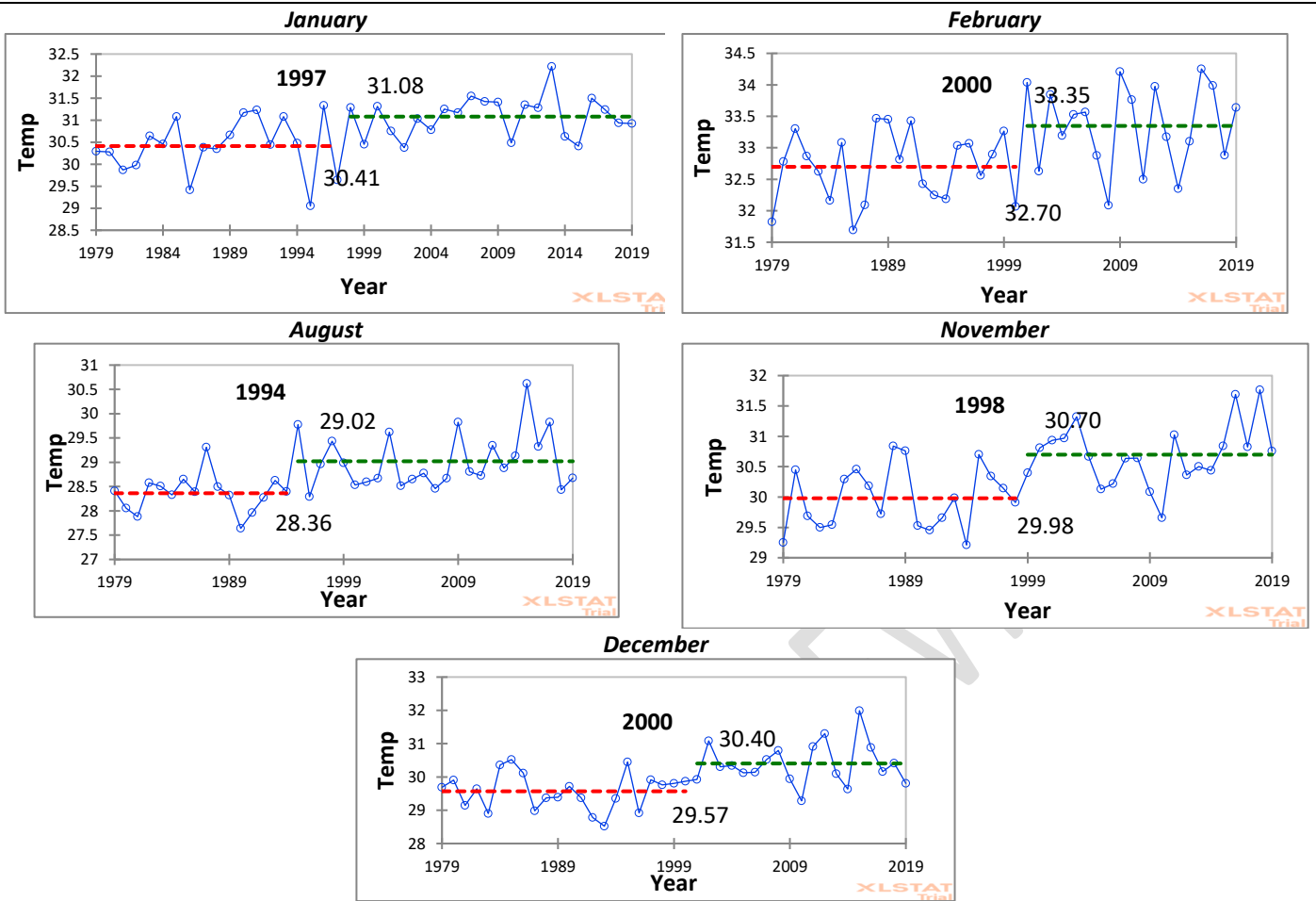
**Fig 3: Pettit's homogeneity shift in monthly mean Minimum temperature of NEDZ**



**Fig 4: Pettit's homogeneity shift in monthly mean maximum temperature of NEDZ**

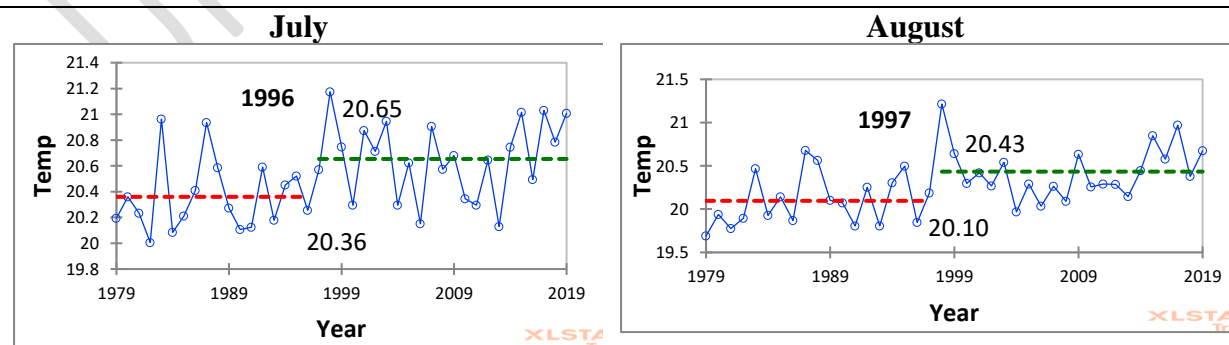
### 3.3 Shift in mean temperature in Northern dry zone during 1979-2019

There was no shift in monthly mean minimum temperature in Northern Dry zone during 1979 to 2019. There is an upward shift during the year 1997 in mean maximum temperature of January month from 30.41 to 31.08 °C (Figure 5). There is an upward shift in the year 2000 for the mean temperature of February and December months from 32.70 to 33.35 °C and 29.57 to 30.40°C, respectively. The maximum temperature of August and November shifted in the years 1994 and 1998 from 28.36 to 29.02 °C and from 29.98 to 30.70°C, respectively. The shift of maximum temperature of various months of Northern Dry Zone of Karnataka was observed during the period 1994 to 2000.

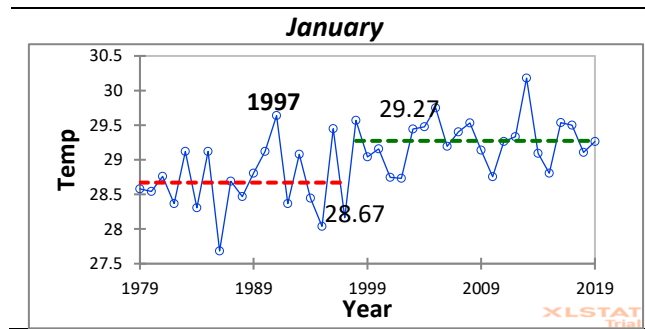


**Fig 5: Pettit's homogeneity shift in monthly mean maximum temperature of NDZ**  
**3.4 Shift in mean temperature in Central Dry Zone during 1979-2019**

The upward shift from 20.36 to 20.65°C took place in the year 1996 in mean minimum temperature of July month. (Figure 6) where as the shift from 20.10 to 20.43°C was recorded in in the year 1997 for the mean minimum temperature of August month. The upward shift of maximum temperature January month occurred (Figure 7) from 28.67 to 29.27 °C in the year 1997. The shift in temperature in Central dry zone identified between 1996 to 1997.



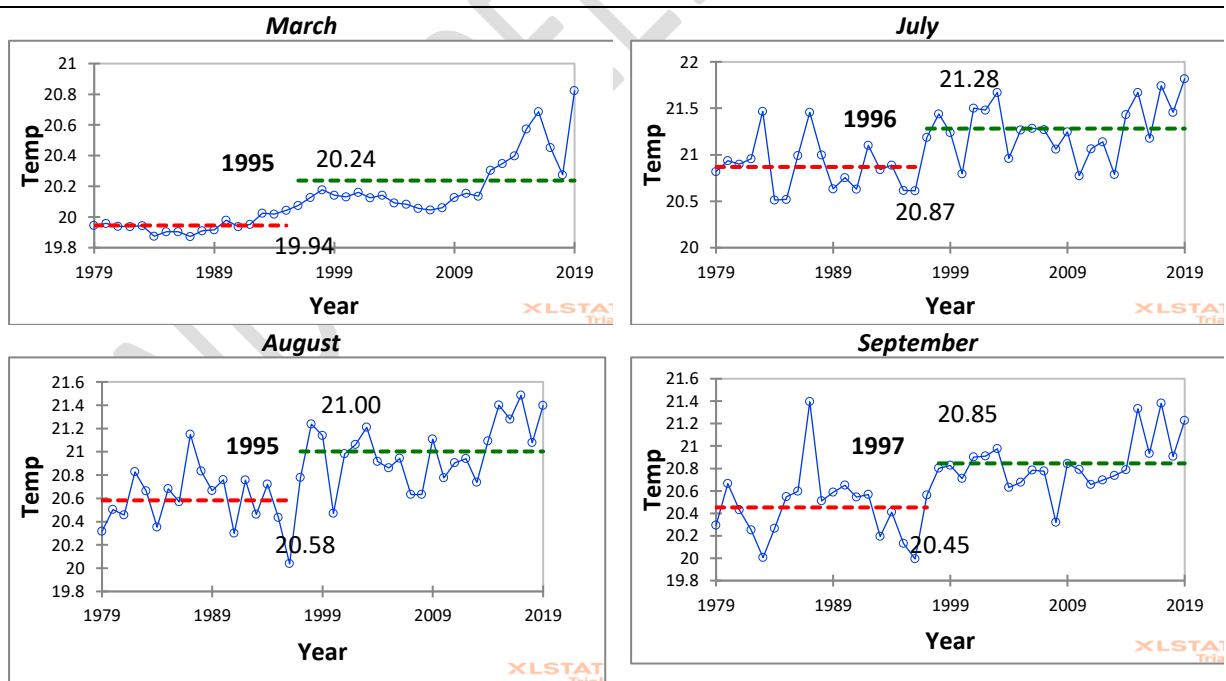
**Fig 6; Pettit's homogeneity shift in monthly mean minimum temperature of CDZ**

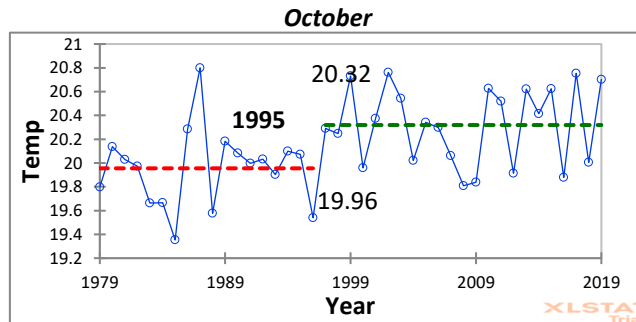


**Fig 7 : Pettit's homogeneity shift in monthly mean maximum temperature of CDZ**

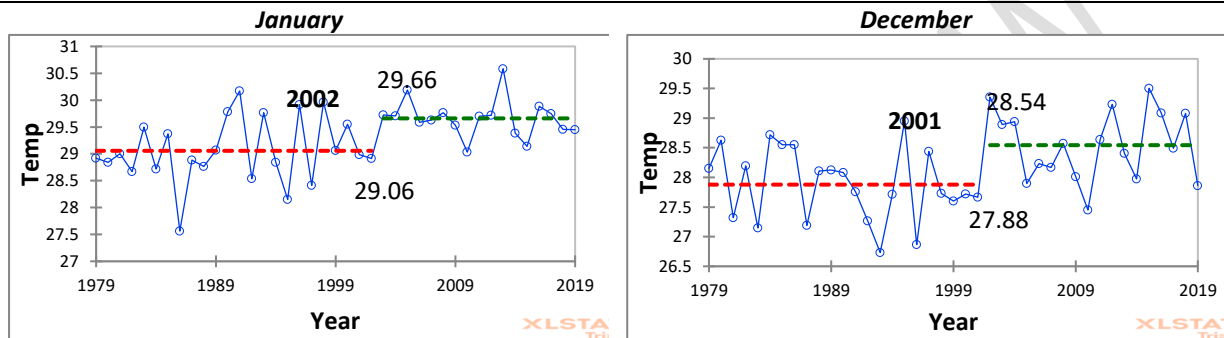
### 3.5 Shift in mean temperature in Eastern Dry Zone during 1979-2019

The shift in mean minimum temperature has occurred more frequently rather than shift in mean maximum temperatures. There is an upward shift during the year 1995 in the mean minimum temperature of March, August and October from 19.94 to 20.24°C, 20.58 to 21.00°C, 19.96 to 20.32°C, respectively (Figure 8). The shift of temperature of July month was from 20.87 to 21.28°C in the year 1996, while that of September was observed in the year 1997 from 20.45 to 20.85°C. The shift of maximum temperatures of January and December months took place (Figure 9) from 29.06 to 29.66°C and 27.88 to 28.54°C, during the years 2000 and 2001, respectively.





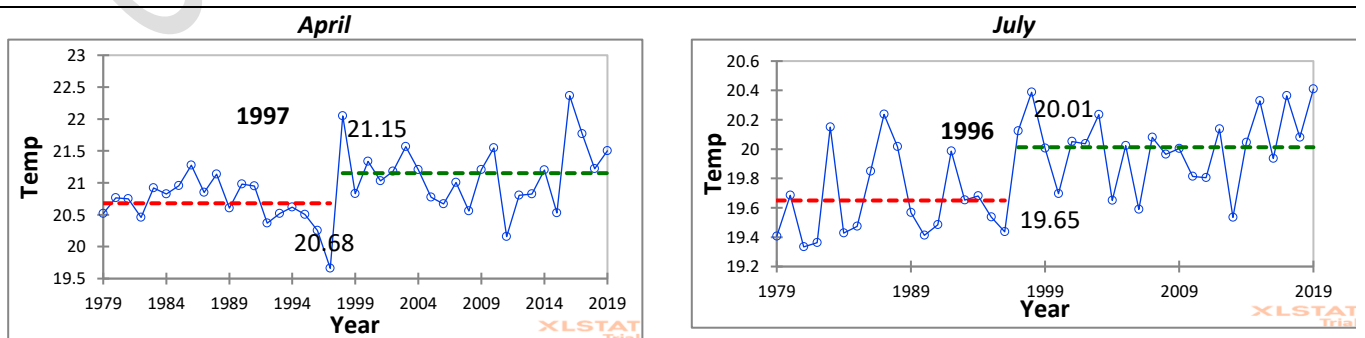
**Fig 8: Pettit's homogeneity shift in monthly mean minimum temperature of EDZ**

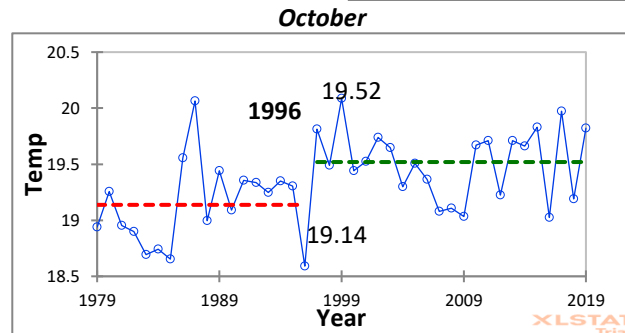
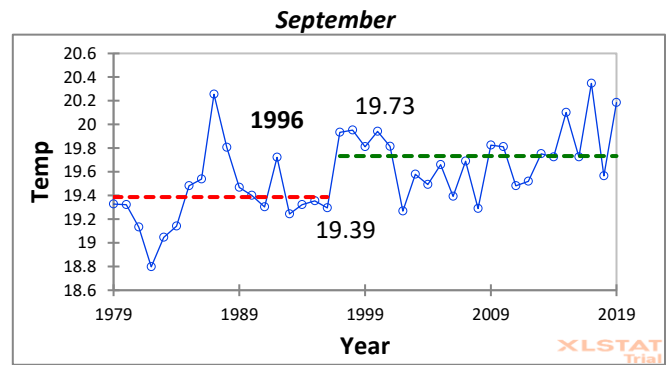
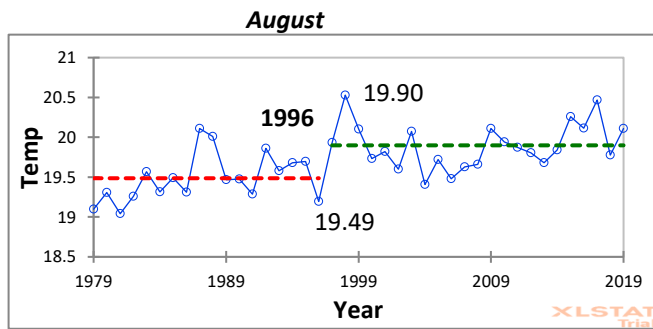


**Fig 9: Pettit's homogeneity shift in monthly mean maximum temperature of EDZ**

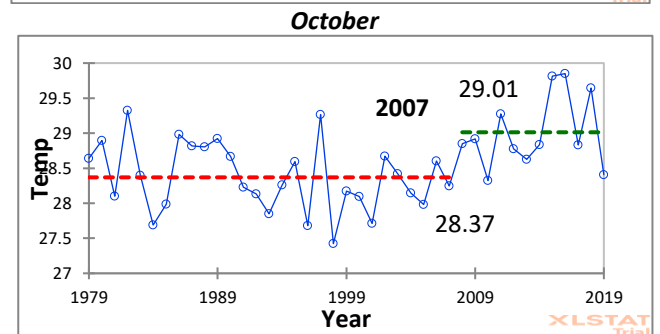
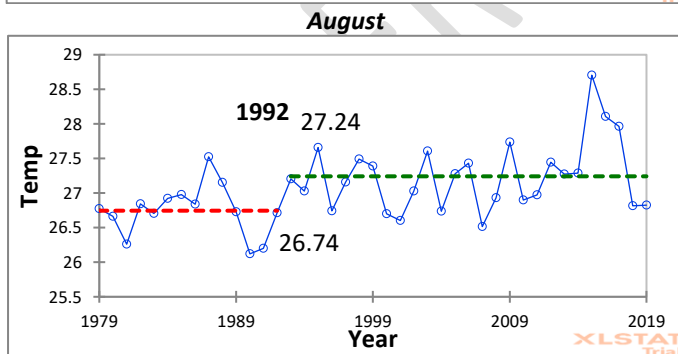
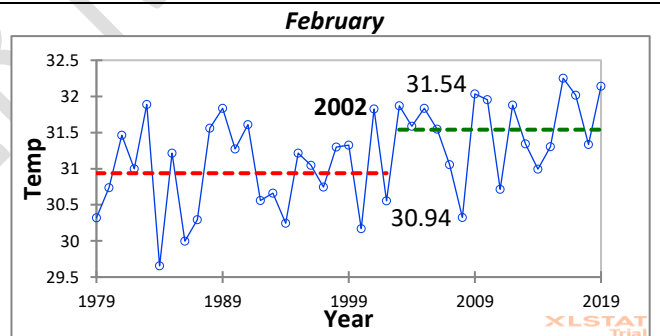
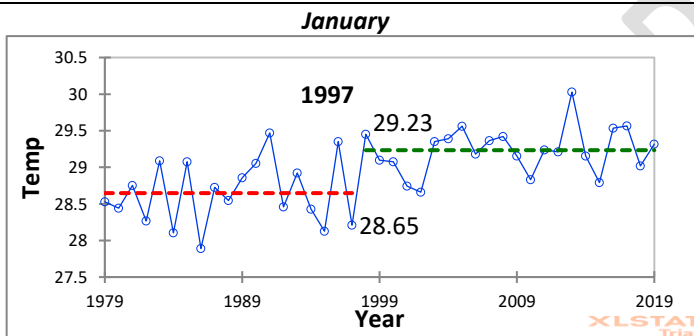
### 3.6 Shift in mean temperature in Southern Dry Zone during 1979-2019

The southern Dry zone recorded larger shifts in monthly mean minimum and maximum temperatures. The upward shift was observed in the year 1997 in mean minimum temperature of April month and the shift was (Figure 10) from 20.68 to 21.15°C. The mean temperatures of July, August, September and October months took place in the year 1996 and the shift was from 19.65 to 20.01°C, 19.49 to 19.90 °C, 19.39 to 19.73°C, 19.14 to 19.52 °C, respectively. The shift in maximum temperature of January (28.65 to 29.23°C), February (30.94 to 31.54°C), August (26.74 to 27.24 °C), October (28.37 to 29.01 °C ) and December (27.91 to 28.50 °C ) months was observed to have taken place in the years 1997, 2002, 1992, 2007 and 2002, respectively (Figure 11).

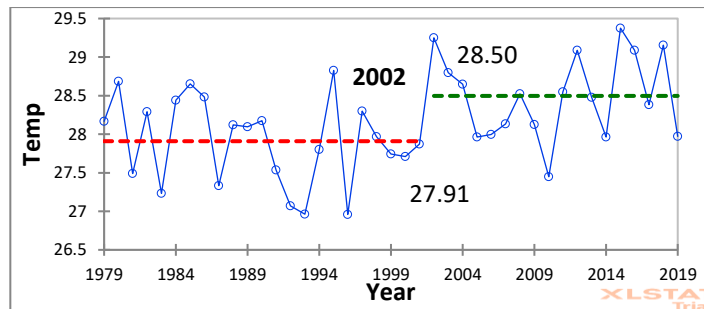




**Fig 10: Pettit's homogeneity shift in monthly mean minimum temperature of SDZ**



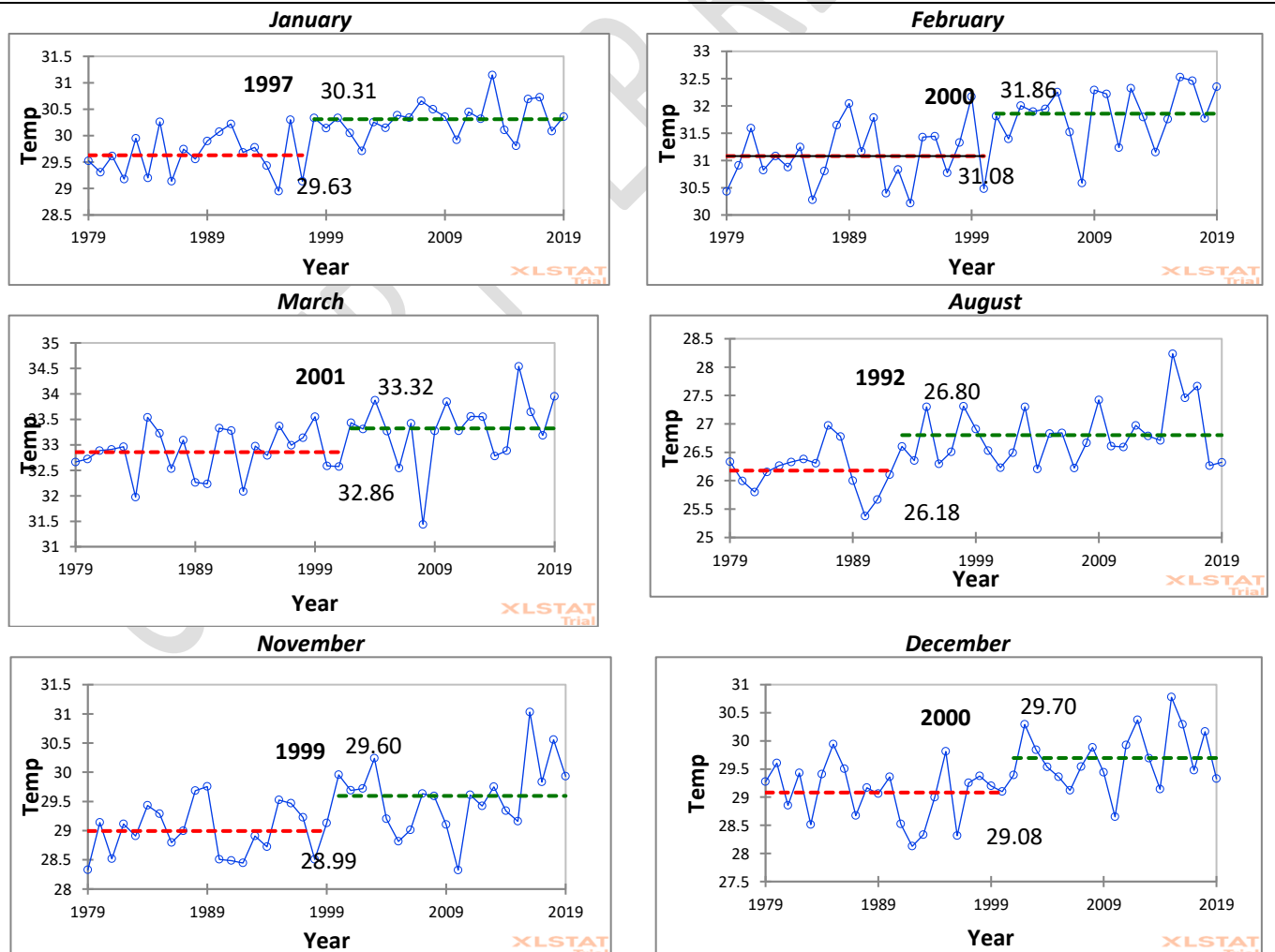
**December**



**Fig 11 : Pettit's homogeneity shift in monthly mean maximum temperature of SDZ**

### 3.7 Shift in mean temperature of Southern Transition Zone during 1979-2019

There are no shifts in mean monthly minimum temperature in Southern Transition Zone during the year 1979 to 2019. The shift in mean maximum temperature of January (from 29.63 to 30.31°C ) and February (29.08 to 29.70 °C ) was observed to have taken place during the years 1997 and 2000, respectively (Figure 12). The shift in mean maximum temperatures of March (from 32.86 to 33.32°C), August (26.18 to 26.80°C) and November ( 28.99 to 29.60°C) was observed to have taken place in the years 2001, 1992 and 1999, respectively.



**Fig 12: Pettit's homogeneity shift in monthly mean maximum temperature of STZ**

### 3.8 Shift in mean temperature of Northern Transition Zone during 1979-2019

The shift in mean minimum temperature of November (from 18.83 to 19.18°C) and December (from 29.56 to 30.40°C) was observed in the years 1989 and (Figure 13) December, respectively. The shift in maximum temperature of January and February was observed during the year 2000 (Figure 14) from 30.87 to 31.43°C and 32.42 to 33.12°C, respectively. The upward shift of mean temperature of August took place in the year 1994 from 27.85 to 28.57°C. During the year 1999 the upward shift was observed in mean maximum temperatures of November (from 30.63 to 31.34 °C) and December (30.24 to 31.05 °C).

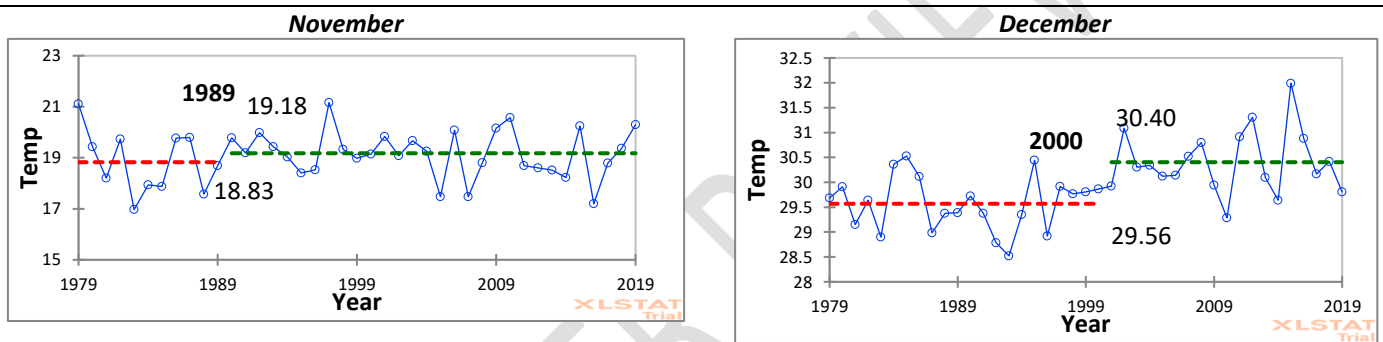
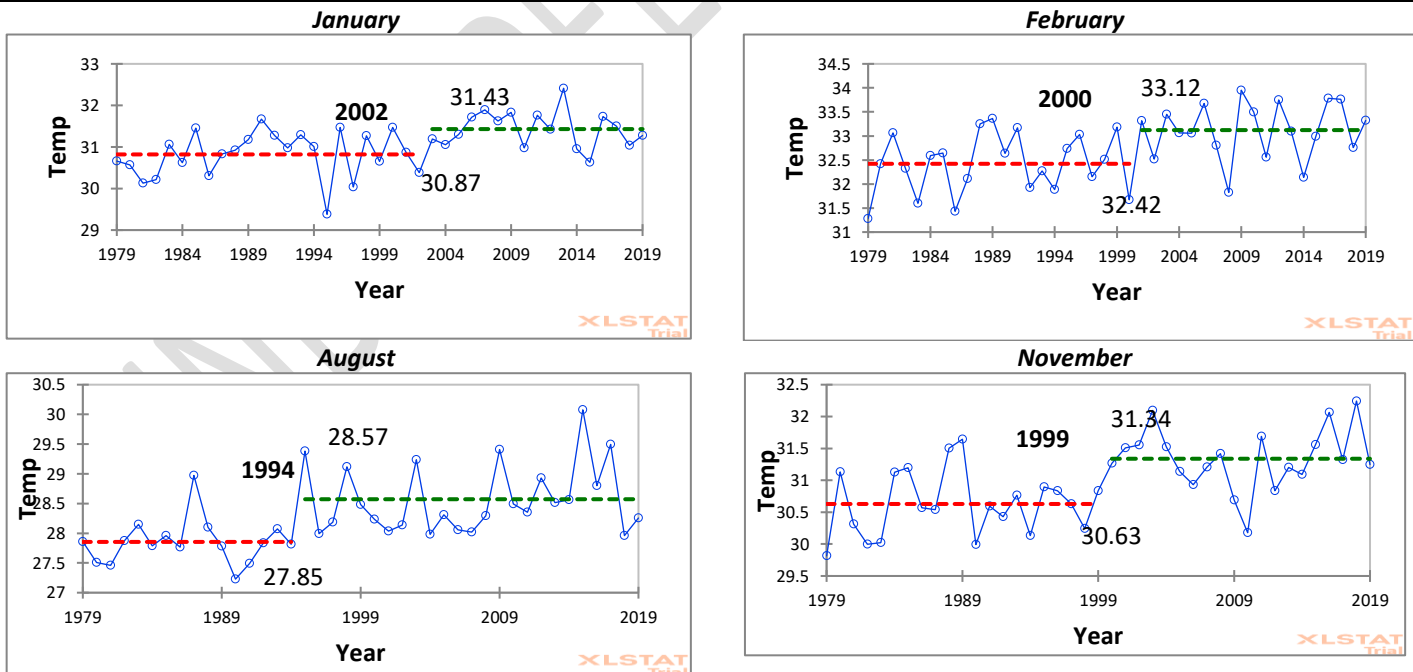
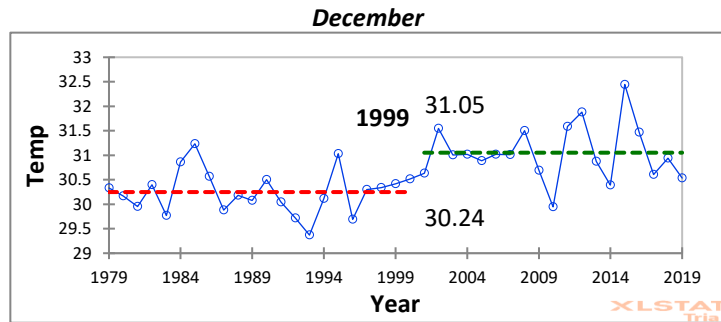


Fig 13: Pettit's homogeneity shift in monthly mean minimum temperature of NTZ

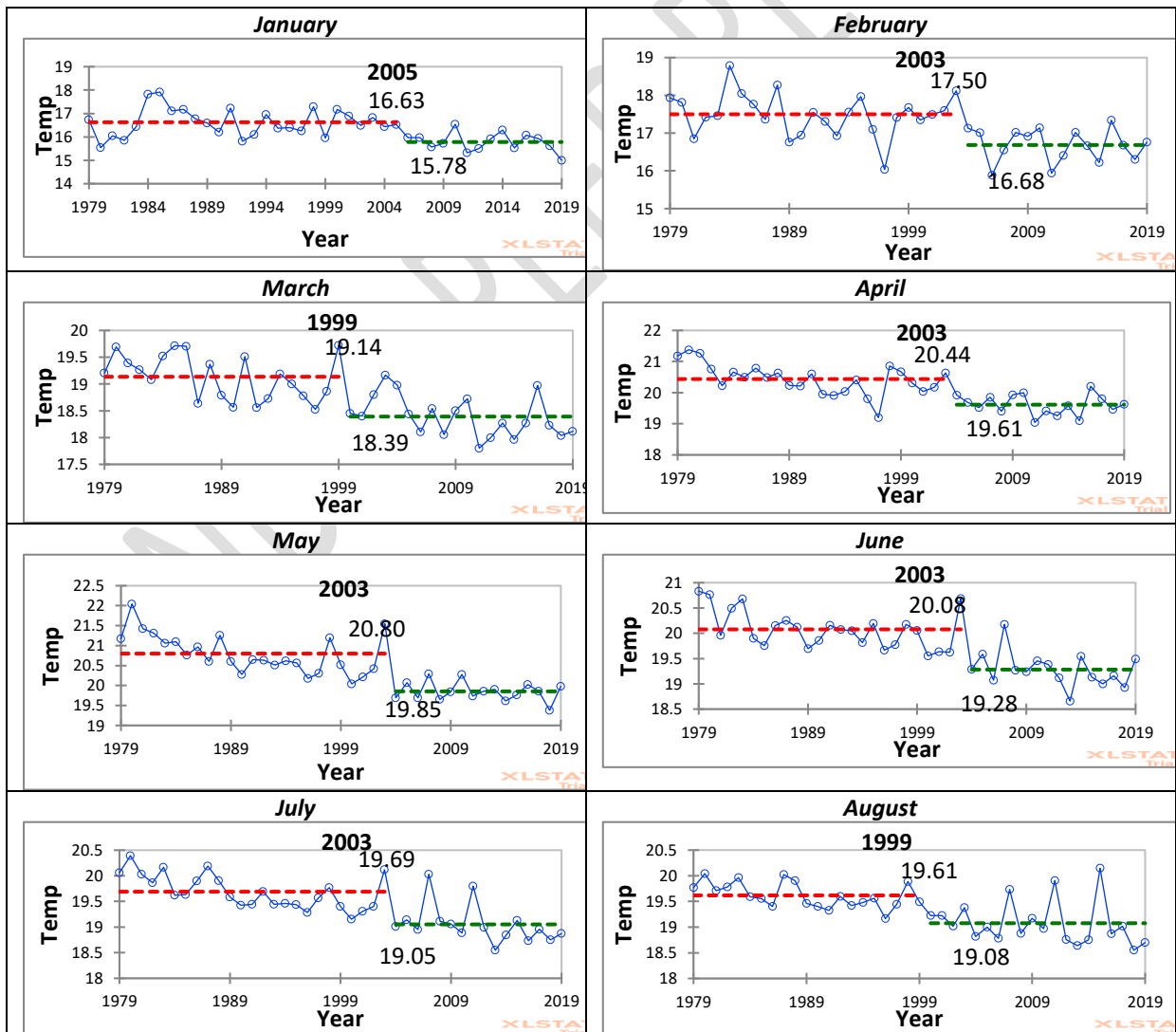




**Fig 14: Pettit’s homogeneity shift in monthly mean maximum Temperature of NTZ**

**3.9 Shift in mean temperature in Hilly Zone during 1979-2019**

There is a downward shift in both minimum and maximum temperatures in all the months. The downward shift of minimum temperature in (Figure 15) of January month was recorded in the year 2005. The downward shift of minimum temperature of February, April, May, June and July was observed to have taken place in the year 2003. The downward shift of maximum temperature of all the months was recorded (Figure 16 ) in different years.



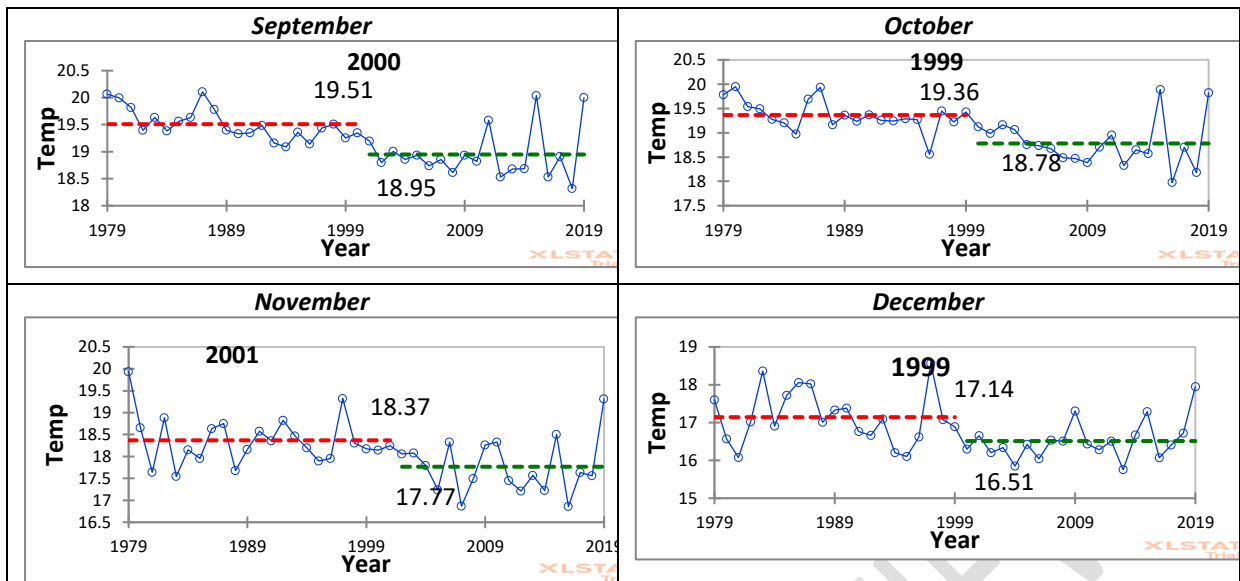
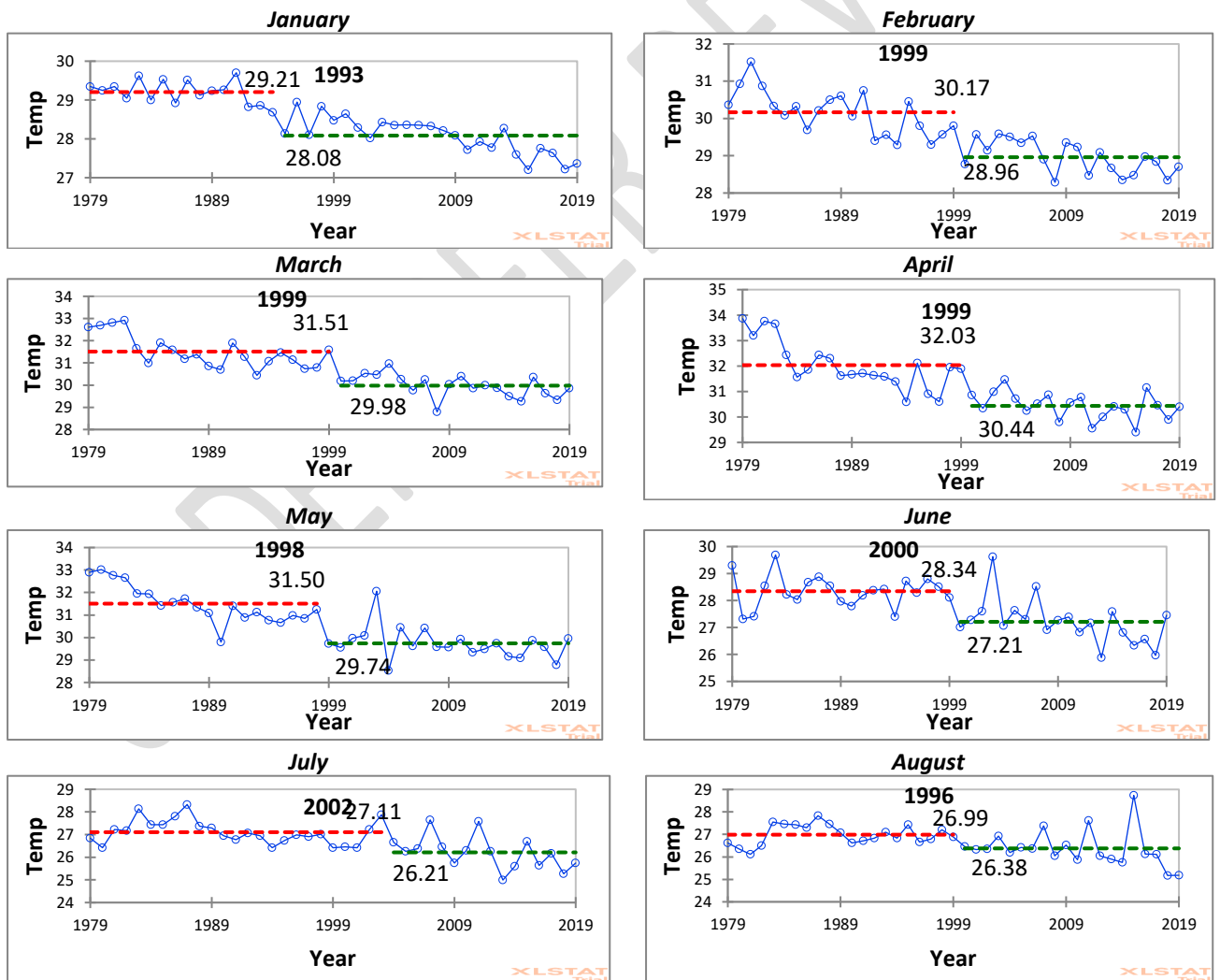


Fig 15: Pettit's homogeneity shift in monthly mean minimum Temperature of HZ



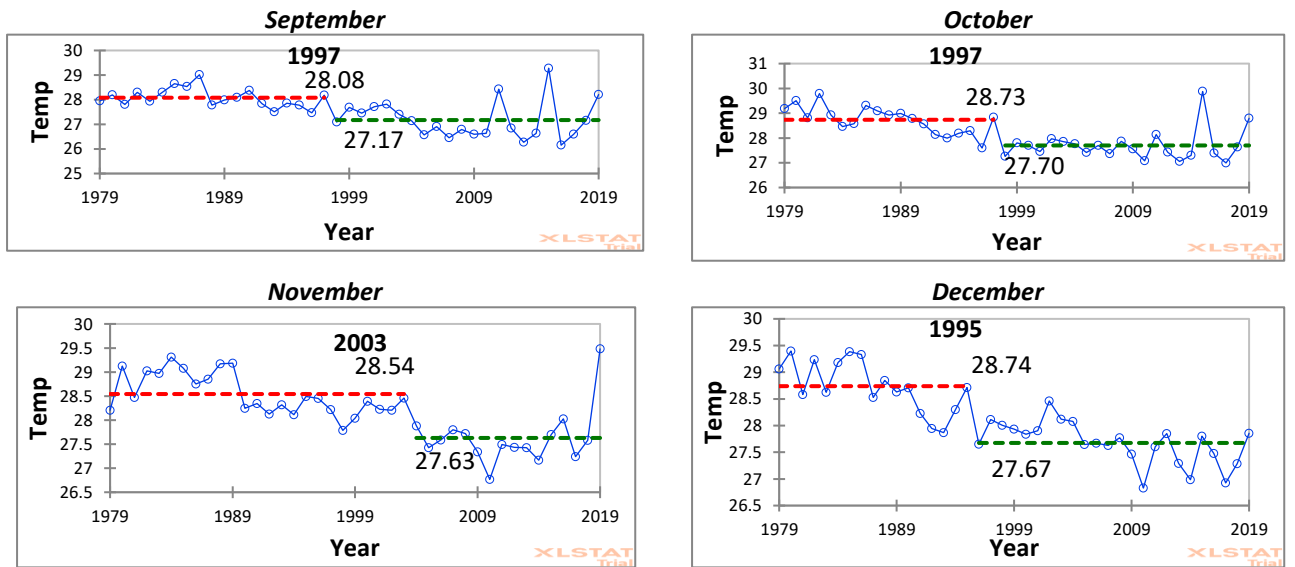
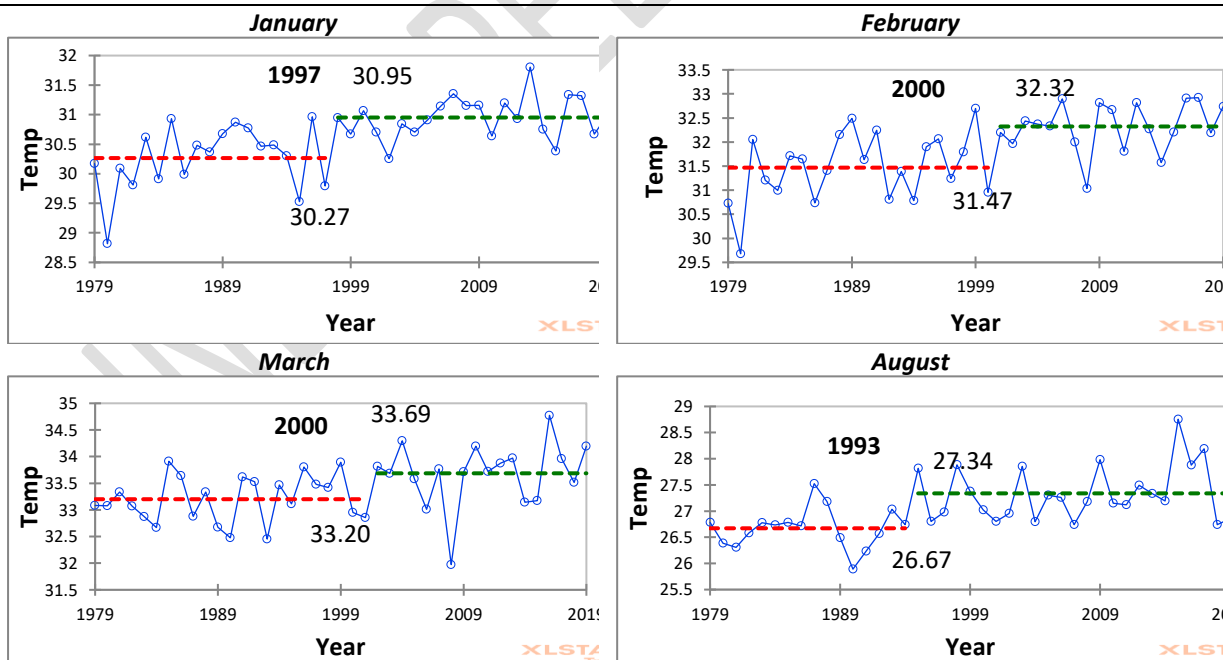


Fig 16: Pettit's homogeneity Shift in monthly mean maximum temperature of HZ

### 3.10 Shift in mean temperature in Coastal Zone during 1979-2019

The upward shift of mean maximum temperature of coastal zone was observed. There is an upward shift from 30.27 to 30.95 °C in (Figure 17) January 1997. The upward shift in temperatures of February (from 31.47 to 32.32°C), March (33.20 to 33.69°C) and December (29.91 to 30.56°C) occurred during the year 2000.



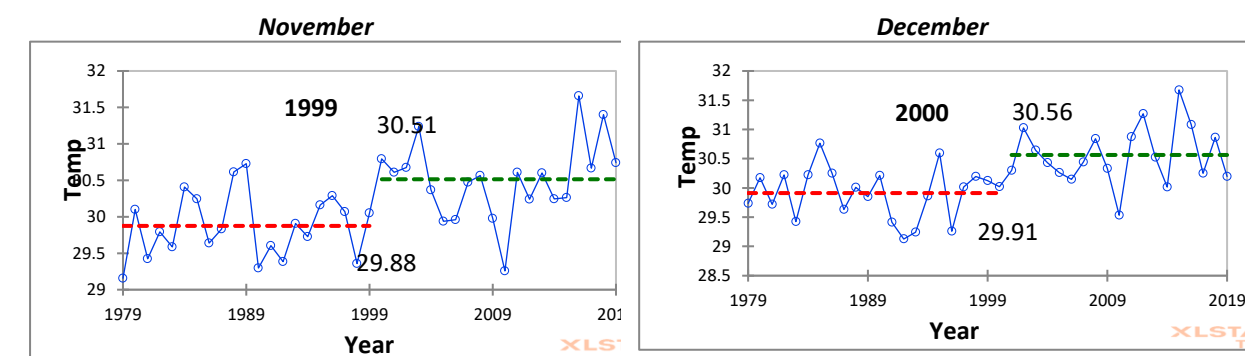


Fig 17: Pettit's homogeneity shift in monthly mean maximum temperature in CZ

Table 1 :Results of the Pettit's homogeneity test and Break year of climate change across ACZ I-V for 1979-2019

	Minimum Temperature( °C)					Maximum Temperature( °C)				
	Mu <sub>1</sub> ( °C)	Mu <sub>2</sub> ( °C)	Shift value ( °C)	Two tailed test (P- Value)	Break Year	Mu <sub>1</sub> ( °C)	Mu <sub>2</sub> ( °C)	Shift value ( °C)	Two tailed test (P- Value)	Break Year
<b>ACZ-I NETZ</b>										
January	-	-	-	-	-	30.11	30.92	0.026	0.046	1999
August	21.81	22.11	0.013	0.023	1994	-	-	-	-	-
November	19.33	17.62	-0.088	0.035	1981	31.28	30.12	-0.037	<0.001	1998
December	-	-	-	-	-	29.16	30.38	0.041	0.000	1998
<b>ACZ-II NEDZ</b>										
January	-	-	-	-	-	31.28	32.16	0.028	0.000	1997
August	22.01	22.28	0.0122	0.031	1997	30.49	31.10	0.020	0.035	1994
November	18.29	18.50	0.011	0.008	1989	30.18	31.18	0.033	0.001	1998
December	-	-	-	-	-	29.30	30.41	0.037	0.000	1998
<b>ACZ-III NDZ</b>										
January	-	-	-	-	-	30.41	31.08	0.022	0.002	1997
February	-	-	-	-	-	32.70	33.35	0.019	0.016	2000
August	-	-	-	-	-	28.36	29.02	0.023	0.000	1994
November	-	-	-	-	-	29.98	30.70	0.024	0.001	1998
December	-	-	-	-	-	29.57	30.40	0.028	0.001	2000
<b>ACZ-IV CDZ</b>										
January	-	-	-	-	-	28.67	29.27	0.020	0.001	1997
July	20.36	20.65	0.014	0.019	1996	-	-	-	-	-
August	20.10	20.43	0.016	0.010	1997	-	-	-	-	-
<b>ACZ-V EDZ</b>										
January	-	-	-	-	-	29.06	29.66	0.020	0.017	2002
March	19.94	20.24	0.015	<0.001	1995	-	-	-	-	-
July	20.87	21.28	0.019	0.001	1996	-	-	-	-	-
August	20.58	21.00	0.020	0.000	1995	-	-	-	-	-
September	20.45	20.85	0.019	<0.0001	1997	-	-	-	-	-
October	19.96	20.32	0.018	0.037	1995	-	-	-	-	-
December	-	-	-	-	-	27.88	28.54	0.023	0.019	2001

Note: Mu<sub>1</sub>-Temperature value before break year; Mu<sub>2</sub>-Temperature value after break year; Shift Value =Mu<sub>2</sub>-Mu<sub>1</sub>/Mu<sub>1</sub>; (p values of the significant change points)

**Table 2 :Results of the Pettit’s homogeneity test and Break year of climate change across ACZ (VI-X) for 1979-2019**

	Minimum Temperature( °C)					Maximum Temperature( °C)				
	Mu <sub>1</sub> ( °C)	Mu <sub>2</sub> ( °C)	Shift value ( °C)	Two tailed test (P- Value )	Break Year	Mu <sub>1</sub> ( °C)	Mu <sub>2</sub> ( °C)	Shift value ( °C)	Two tailed test (P- Value )	Break Year
<b>ACZ-VI SDZ</b>										
January	-	-	-	-	-	28.65	29.23	0.020	0.000	1997
February	-	-	-	-	-	30.94	31.54	0.019	0.017	2002
April	20.68	21.15	0.022	0.018	1997	-	-			-
July	19.65	20.01	0.018	0.002	1996	-	-			-
August	19.49	19.90	0.021	0.001	1996	26.74	27.24	0.018	0.039	1992
September	19.39	19.73	0.017	0.004	1996	-	-			-
October	19.14	19.52	0.019	0.011	1996	28.37	29.01	0.022	0.030	2007
December	-	-	-	-	-	27.91	28.50	0.0211	0.043	2002
<b>ACZ-VII STZ</b>										
January	-	-	-	-	-	29.63	30.31	0.022	<0.0001	1997
February	-	-	-	-	-	31.08	31.86	0.025	0.000	2000
March	-	-	-	-	-	32.86	33.32	0.013	0.030	2001
August	-	-	-	-	-	26.18	26.80	0.023	0.004	1992
November	-	-	-	-	-	28.99	29.60	0.021	0.012	1999
December	-	-	-	-	-	29.08	29.70	0.021	0.005	2000
<b>ACZ-VIII NTZ</b>										
January	-	-	-	-	-	30.83	31.43	0.091	0.009	2002
February	-	-	-	-	-	32.42	33.12	0.021	0.008	2000
August	-	-	-	-	-	27.85	28.57	0.025	<0.0001	1994
November	18.83	19.18	0.018	0.046	1989	30.63	31.34	0.023	0.001	1999
December	29.56	30.40	0.028	0.694 NS	2000	30.24	31.05	0.026	<0.0001	1999
<b>ACZ-IX HZ</b>										
January	16.63	15.78	-0.051	0.000	2005	29.21	28.08	-0.038	<0.0001	1993
February	17.50	16.68	-0.046	0.000	2003	30.17	28.96	-0.040	<0.0001	1999
March	19.14	18.39	-0.039	<0.0001	1999	31.51	29.98	-0.048	<0.0001	1999
April	20.44	19.61	-0.040	<0.0001	2003	32.03	30.44	-0.049	<0.0001	1999
May	20.80	19.85	-0.045	<0.0001	2003	31.50	29.74	-0.055	<0.0001	1998
June	20.08	19.28	-0.039	<0.0001	2003	28.34	27.21	-0.039	<0.0001	2000
July	19.69	19.05	-0.032	<0.0001	2003	27.11	26.21	-0.033	0.001	2002
August	19.61	19.08	-0.027	0.000	1999	26.99	26.38	-0.022	0.004	1996
September	19.51	18.95	-0.028	0.000	2000	28.08	27.17	-0.032	0.000	1997
October	19.36	18.78	-0.029	<0.0001	1999	28.73	27.70	-0.035	<0.0001	1997
November	18.37	17.77	-0.032	0.019	2001	28.54	27.63	-0.031	<0.0001	2003
December	17.14	16.51	-0.036	0.010	1999	28.74	27.67	-0.037	<0.0001	1995
<b>ACZ-X CZ</b>										
January	-	-	-	-	-	30.27	30.95	0.022	<0.0001	1997
February	-	-	-	-	-	31.47	32.32	0.027	0.001	2000
March	-	-	-	-	-	33.20	33.69	0.014	0.012	2000
August	-	-	-	-	-	26.67	27.34	0.025	0.001	1993
November	-	-	-	-	-	29.88	30.51	0.021	0.003	1999
December	-	-	-	-	-	29.91	30.56	0.021	0.000	2000

**Note: Mu<sub>1</sub>-Temperature value before break year; Mu<sub>2</sub>-Temperature value after break year; Shift Value =Mu<sub>2</sub>-Mu<sub>1</sub>/Mu<sub>1</sub>; (p values of the significant change points)**

#### 4. CONCLUSION

The upward shift in mean temperature was experienced between 1994 and 1999 across different agro-climatic zones of Karnataka except in Hilly zone. Researchers should develop crop varieties that are insensitive to temperature changes. The scientist should develop packages of practices which will mitigate adverse effect of fluctuations in climate parameters on crop productivity. The state is surrounded by rivers Krishna in the north, Cauvery in the south and Tungabhadra in the central part. Therefore, there is a great need and scope for development of irrigation sources. Investment should be made in creating micro irrigation and water harvesting structures like check dams, farm ponds which helps the farmers to increase crop production. There is a need for government programs to educate farmers and provide them with more localized information on climate forecasts, climate change and droughts.

#### *Data Availability*

Data is available with authors and will be provided on request

#### 5. REFERENCES

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