Trend Analysis of Temperature and Rainfall across Agro Climatic Zones of Karnataka-A Semi Arid State in India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

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ABSTRACT

The study was carried out for ten Agro climatic zones in Karnataka state in India. The temperature and rainfall data were used for analysis from 1979-2019 which is about 40 years. Understanding spatiotemporal rainfall pattern, Rainfall Anomaly Index which is drought indicator technique was used to classify the positive and negative severities in rainfall anomalies. The RAI ranges below 0.2 are considered as dry zone. The analysis resulted that, all zones are falls in category of dry zone with range of 0.2 to 0.4. For past five years, North Eastern Transition Zone was noted maximum times falling in the range of RAI below 0.2 and near to zero. Statistical techniques like linear trend estimation, R square was used for trend estimation across annual, seasonal to identify the variation in the temperature across different zones. The meaningful statistically significant achieves when there is $r^2 \geq 0.65$ and $p \leq 0.05$. It was analysed that, hilly Zone experienced decreased trend in both minimum and maximum temperature in all seasons which ultimately reflected in annual temperature to decrease with high R square values.

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1. INTRODUCTION

For several decades, Industrial revolution in developing countries and destroying of forests for fuel in developing nations became a reason for growth of green house gas emissions which raises the earth's temperature. The accelerating pace of climate change is likely to affect the agricultural production in general and food security in particular. The available evidence from various climate change impact studies suggests that the developing countries are likely to get more adversely affected than the developed countries due to their typical geographical location and large dependence on climate sensitive sectors like agriculture. Higher temperature eventually reduces yields of desirable crops while encouraging weed and pest proliferation [1-3]. Changes in precipitation patterns increase the likelihood of short-run crop failures and long-run production declines.

India, a sub-tropical country is highly sensitive to climate change. The main reason for its high sensitivity is the variability in rainfall. About 80 per cent of the total rainfall over India occurs during the four months from June to September as a result of the south-west monsoon. Agricultural activities are very sensitive to climate and weather conditions [4-6]. Indian Agriculture despite of its declining share in National income continues to be important sector of the economy because of its strategic importance to food security, livelihood and poverty reduction. Among the agro ecological zones in India, Semi arid zone plays a prominent place in economy, contributing about 42 percent of total food grain production, supporting 60 percent of livestock population and employing nearly 37 percent of marginal farmers through agricultural activities [7,8]. This zone comprises parts of Andhra Pradesh, Karnataka, Tamil Nadu , Deccan plateau, parts of Gujarat and Maharashtra with cultivation of major crops like Rice, Wheat, Sugarcane, Pulses, sorghum, Tur. Despite of its greater vegetation with 62 percent of cropped area and 55 percent of net sown area , this zone is susceptible with famine , water shortages land degradation and consider as most drought area with 34% (112 of 329 million ha).

Karnataka is one of the major agrarian states which is often affected by natural calamities and it ranks second after Rajasthan in terms of drought prone with 50 percent of the area as semi arid with districts having frequent unequal distribution of rainfall for every 5 years and severe drought conditions for once in every 8-9 years [9]. The state collaborated between the Department of Agriculture and the University of Agricultural Sciences has come up with 10 distinct Agro-climatic zones based on soil characteristics, rainfall distribution, irrigation pattern, cropping pattern ,ecological and social characteristics viz., Central Dry zone , Eastern Dry zone , Northern Dry zone , North Eastern Dry zone , Southern dry zone, North transition zone North eastern transition zone , Southern transition zone ,Coastal zone and Hilly zone [10]. There are five dry zones with relatively low rainfall [10-12]. Three transitional zones with relatively high rainfall while Hilly and coastal zones receives highest rainfall of more than 1500 mm mean annual rainfall. The rainfall and temperatures [13] are the most important fundamental physical parameters among the climate as these parameters determine the environmental condition of the particular region which affects the agricultural productivity [14,15]. The spatial and temporal feature of rainfall necessitates the need to examine its changing pattern in response to changing temperature because rainfall is one of the most important parameters that influence the agriculture of a region and food production ,thus effecting the socio economic status of resource poor marginal and small farmers. The trend analysis of rainfall [16-19] temperature [20-22] and other climatic variables on different spatial scales will help in the construction of future climate scenarios.

2. METHODOLOGY

Temperature and rainfall trends observed in different zones over a period of 40 years are presented. Climatic variables like daily rainfall, temperature across Karnataka state were collected from IMD. Although there are certain limitations of secondary data based assessments such as authenticity of data, data inconsistency in some cases and data gaps still the assessments provides a useful means of assessment at the macro level. Statistical methods are used in determining the form of a trend, estimating the trend itself along with some measure of uncertainty and in determining the statistical significance of a trend

2.1 Linear Trend Equation and R Square

Most line equations are in the form Y = MX + C with Y as your variable on the y-axis, M as the slope or coefficient of the X variable, which is the

values on your y-axis, C is the constant or value when no X value is present. R-squared (R^2): It is a statistical measure that represents the proportion of the variance for a dependent variable that's explained by an independent variable or variables in a regression model. R-squared explains to what extent the variance of one variable explains the variance of the second variable. So, if the R^2 of a model is 0.50, then approximately half of the observed variation can be explained by the model's inputs.

R-squared (R^2)= 1-Unexplained variation /Total variation

Rainfall Anomaly Index (RAI), developed by Rooy [23], is used to classify the positive and negative severities in rainfall anomalies. The RAI considers two anomalies, i.e., positive anomaly and negative anomaly. First, the precipitation data are arranged in descending order. The ten highest values are averaged to form a threshold for positive anomaly and the ten lowest values are averaged to form a threshold for negative anomaly. The arbitrary threshold values of +3 and -3 have, respectively, been assigned to the mean of the ten most extreme positive and negative anomalies. Nine abnormality classes, ranging from extremely wet to extremely dry conditions, are then given against a scale of numerical values of the relative rainfall anomaly index. The positive anomalies have their values above average and negative anomalies have their values below average.

For positive anomalies RAI= 3 (RNF-RNF_m/X-RNF_m)   (1)

For negative anomalies RAI= -3 (RNF-RNF_m/Y-RNF_m)   (2)

Where, RNF = current monthly/yearly rainfall (mm)
RNF_m = monthly/yearly average rainfall of the historical series (mm);
X= average of the ten highest monthly/yearly precipitations of the historical series (mm);
Y= average of the ten lowest monthly/ yearly precipitations of the historical series (mm)

3. RESULTS AND DISCUSSION

The increasing and decreasing temperature and precipitation trends were analyzed using daily temperature and precipitation data for ten Agro Climatic zones, spatially distributed across Karnataka. Although trend analysis is often used to predict future events, it could be used to estimate uncertain events in the past. In particular, the weather data exhibit an increasing or decreasing trend that can be statistically distinguished from random behaviour. For trend analysis of temperature, linear trend estimation and R^2 was used .Rainfall Anomaly Index used for Rainfall drought intensity level.

3.1 Linear Trend Estimation of Temperature across Agro Climatic Zones 1978-79 to 2018-2019

The positive trend in temperature has observed in all zones while negative trend has been recorded in Hilly Zone (Table 2) which is strongly explained by R^2 of 74 percent and 87 percent in minimum and maximum temperature respectively.

During winter, It was noticed that, there is a negative trend in minimum temperature of all zones except in SDZ (Table 3).While, positive trend in maximum temperature has been noticed in all zones except in HZ for which R^2 is strongly explained by 86 percent. It concluded that, Hilly zone was less hot when compared to other zones.

Table 1. Classification Rainfall Anomaly Index intensity

RAI Range	Classification
Above 4	Extremely humid
2 to 4	Very humid
0 to 2	humid
-2 to 0	Dry
-4 to -2	Very dry
Below -4	Extremely dry

Source:Freitas [24] adapted by Araujo et al. [25]

During summer, It was noticed that, there is a negative trend in minimum temperature of HZ and positive trend in all zones (Table 4) .While, maximum temperature has been noticed in all zones except in HZ which showed decreased trend for which R^2 is strongly explained by 80 percent.

There is a change in trend in minimum temperature of all agro climatic zones. It was further recorded that, trend has been upward slope in all zones except in HZ (Table 5).While the trend in maximum temperature has been noticed positively in all zones.

Table 2. Trend equation and R² for Annual Trend of Karnataka

ACZ	ANNUAL	Minimum Temperature		Maximum Temperature	
		Trend Equation	R^2	Trend Equation	R^2
ACZ-I	NETZ	0.001X+17.84	0.000	0.019X+33.04	0.348
ACZ-II	NEDZ	-0.000x+21.04	6e-05	0.018x+33.15	0.346
ACZ-III	NDZ	0.000X+20.28	0.001	0.015X+31.51	0.399
ACZ-IV	CDZ	0.005x+19.13	0.050	0.011x+29.87	0.183
ACZ-V	EDZ	0.011x+19.58	0.215	0.012x+30.98	0.231
ACZ-VI	SDZ	0.012X+18.62	0.219	0.013X+29.38	0.279
ACZ-VII	STZ	0.007x+19.13	0.084	0.016x+29.46	0.417
ACZ-VIII	NTZ	0.001X+20.48	0.001	0.016x+31.26	0.427
ACZ-IX	HZ	-0.030X+19.38	0.74	-0.051X+29.76	0.872
ACZ-X	CZ	0.005x+19.96	0.049	0.018x+30	0.507

Source: Author's calculation based on data availability from IMD (1978-79 to -2018-2019)

Table 3 Trend equation for Winter (January –February)of Karnataka

ACZ	Winter	Minimum Temperature		Maximum Temperature	
		Trend Equation	R^2	Trend Equation	R^2
ACZ-I	NETZ	-0.019x+17.06	0.069	0.024X+31.41	0.131
ACZ-II	NEDZ	-0.021x+17.78-	0.085	0.030x+32.07	0.239
ACZ-III	NDZ	-0.014X+17.15	0.061	0.026X+31.33	0.346
ACZ-IV	CDZ	-0.01x+16.45	0.026	0.021x+29.69	0.26
ACZ-V	EDZ	-0.002x+16.773	0.001	0.020x+30.20	0.191
ACZ-VI	SDZ	0.001X+16.10	0.001	0.023X+29.57	0.326
ACZ-VII	STZ	-0.005Xx+16.44	0.008	0.03x+30.08	0.494
ACZ-VIII	NTZ	-0.013X+17.35	0.049	0.025X+31.36	0.355
ACZ-IX	HZ	-0.030x+17.39	0.364	-0.055X+30.20	0.867
ACZ-X	CZ	-0.010x+17.45	0.030	0.034x+30.52	0.491

Source: Author's calculation based on data availability from IMD (1978-79 to -2018-2019)

Table 4. Trend equation for Summer (March –May) of Karnataka

ACZ	Summer	Minimum Temperature		Maximum Temperature	
		Trend Equation	R^2	Trend Equation	R^2
ACZ-I	NETZ	0.006x+23.52	0.019	0.015X+38.51	0.064
ACZ-II	NEDZ	0.004x+23.81	0.009	0.011x+38.42	0.046
ACZ-III	NDZ	0.004X+22.22	0.013	0.008X+35.92	0.036
ACZ-IV	CDZ	0.007x+20.91	0.037	0.001x+33.79	0.000
ACZ-V	EDZ	0.011x+21.45	0.182	0.003x+35.28	0.005
ACZ-VI	SDZ	0.011X+20.12	0.108	0.004X+33.00	0.008
ACZ-VII	STZ	0.009x+20.62	0.065	0.009x+32.83	0.045
ACZ-VIII	NTZ	0.005X+22.16	0.018	0.012X+35.07	0.098
ACZ-IX	HZ	-0.038x+20.57	0.677	-0.077X+32.50	0.800
ACZ-X	CZ	0.0009x+21.40	0.060	0.011x+33.24	0.085

Source: Author's calculation based on data availability from IMD (1978-79 to -2018-2019)

Table 5 Trend equation for South west Monsoon (June –September) of Karnataka

ACZ	SWM	Minimum Temperature		Maximum Temperature	
		Trend Equation	R^2	Trend Equation	R^2
ACZ-I	NETZ	0.0009x+22.33	0.113	0.006X+32.01	0.012
ACZ-II	NEDZ	0.007x+22.45	0.084	0.008x+32.03	0.023
ACZ-III	NDZ	0.006X+21.60	0.070	0.009X+29.55	0.051
ACZ-IV	CDZ	0.011x+20.22	0.190	0.009x+28.42	0.056
ACZ-V	EDZ	0.015x+20.72	0.339	0.009x+29.96	0.068
ACZ-VI	SDZ	0.015X+19.54	0.334	0.013X+27.67	0.136
ACZ-VII	STZ	0.010x+20.14	0.148	0.012x+27.12	0.133
ACZ-VIII	NTZ	0.005X+21.87	0.054	0.010X+29.02	0.074
ACZ-IX	HZ	-0.029x+20.15	0.635	0.0037X+28.00	0.484
ACZ-X	CZ	0.009x+20.95	0.122	0.012x+27.62	0.136

Source: Author's calculation based on data availability from IMD (1978-79 to -2018-2019)

Table 6.Trend equation for north east monsoon (October-December) of Karnataka

ACZ	NEM	Minimum Temperature		Maximum Temperature	
		Trend Equation	R^2	Trend Equation	R^2
ACZ-I	NETZ	0.001x+17.84	0.000	0.034X+30.07	0.269
ACZ-II	NEDZ	0.001x+18.57	0.001	0.031x+30.11	0.268
ACZ-III	NDZ	-0.000X+18.48	5E-05	0.023X+29.85	0.250
ACZ-IV	CDZ	0.007x+17.66	0.029	0.016x+28.01	0.161
ACZ-V	EDZ	0.015x+18.09	0.133	0.017x+28.55	0.168
ACZ-VI	SDZ	0.014X+17.58	0.122	0.017X+27.92	0.197
ACZ-VII	STZ	0.010x+18.09	0.052	0.021x+28.78	0.268
ACZ-VIII	NTZ	6E.05X+19.04	1E-05	0.022X+30.36	0.254
ACZ-IX	HZ	-0.023X+18.49	0.283	-0.042X+29.06	0.625
ACZ-X	CZ	0.007x+18.85	0.026	0.021x+29.58	0.296

Source: Author's calculation based on data availability from IMD (1978-79 to -2018-2019)

The change in trend in minimum temperature has been observed positively in all zones except in NDZ,HZ (Table 6) .While the change in trend in maximum temperature has been noticed positively in all zones except in HZ which is explained by R^2 with 62 percent. As a whole it is noticed that, Hilly Zone is experiencing decreasing trend in both minimum and maximum temperature in all seasons and ultimately reflected in annual temperature to decrease. The annual maximum temperature has increased in dry zones, transitional and Coastal zone.

3.2 Rainfall Anomaly Index (RAI) Across Agro Climatic Zones for 40 years (1978-79 to -2018-2019)

ACZ I: Among transitional zones, North Eastern Transition zone is most drought effected as RAI=0 was recorded in the years 1981,1987,1989,1990,1995,1996,2000,2008,2013,2017 and 2019 (Fig. 1) which is of totally accounted to 11 drought most years among all agro climatic zones and few years experiencing RAI between 0.5 to 0.7.

ACZ-II: For the North Eastern Dry zone , the years 1982,2001,2003 experienced RAI =0 (Fig 2) and many years in the range of RAI=0.38 which comes under category of 0.5 .

ACZ III: The northern Dry Zone also experienced RAI =0 in the year 1991,1992, 2000, 2017 (Fig. 3) and more number years it experience RAI nearer to 0.25.

ACZ IV: There was notable rainfall variability in central Dry zone between 1983 and 2019. Results showed with persistent near average (RAI = 0) rainfall in 1883, 1986 , 1992, 1996 and only once reaching (RAI =+2) in 2003 (Fig 4) while for many years RAI range below 0.5 for central dry zone.

ACZ V: The eastern Dry zone reaches RAI =0 (with less than 0.05 RAI) for 5 years 1983, 1986, 1999, 2009 , 2013 while zone experienced RAI=+1.5 in the year 2002 (Fig 5) and majority of the years Zone has RAI below 0.5 during this 40 years .

ACZ VI: The southern Dry zone is one of the climatic zone which experienced more number of years 1979, 1980,1983,1988 ,2007 with (RAI =0) and many years experienced RAI <0.2 which indicates the dry and drought climate and low rainfall in this zone when comparison to other zones and experienced only for years 2003 with RAI +1.5 (Fig. 6) and few years in the range of RAI +0.3.

ACZ VII: Southern Transition zone recorded with (RAI =0) for years 182,1983,2004,2008 (Fig 7) and many years have recorded RAI between 0.4 to 0.8 which indicates the zone has received good amount rainfall and few years have fallen in the range of RAI <0.2.

ACZ VIII: It was observed that, Northern Transition Zone experienced (RAI =0) only in the year 2000 and many years have experienced RAI between 0.4 to 1.2 (Fig. 8) and only few years fall into the category of RAI =0.15.

.ACZ IX: Hilly zone experienced RAI =0 in 1993,1997, 2004,2010 and 2018 and many years experienced RAI =+0.4 in this zone (Fig 9) .When comparison to all zones , Hilly and coastal zones are least drought effected as it receives more than 1500mm average annual rainfall.

ACZ X: Coastal Zone recorded RAI =0 in the year 1984,1995 and 2004 , while many years experienced RAI =+0.7 (Fig. 10).

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Comparative analysis for five years of rainfall pattern from 2015-2019 for 10 agro climatic zones (Fig .11) resulted that, North Eastern Transition Zone recorded more times of RAI =0 in the year 2016,2017 , 2019 followed by Northern Transition zone which was in second place with RAI = +0.1 .

In the Western Ghats, the IISc revealed the loss of evergreen forest cover from 16% to 11% from 1985 to 2018 with the increase in anthropogenic pressure owing to unplanned developmental activities. The study reported that, the loss of forest cover has affected the local rainfall subjected to t changes in heat and weather processes which cause extreme weather conditions. Lower evapo transpiration with deforestation across the region caused a delay in onset of the rainy season and decline in the number of rainy days with higher dry conditions. (Indian State of Forest report 2019). In addition to this deforestation, the occurrence of extreme weather events has increased both in terms of frequency and intensity across Karnataka in the last decades. It was recorded that, the hydro-

meteorological disasters such as drought, flood, hailstorm, cyclone, heat wave, thunder storm and lighting events have occurred in the state more frequently in recent years [9]. Between 2001 and 2019, the state has experienced a drought of varying severity for 15 years and experienced severe floods in 2005, 2009, 2018 and 2019. The recurrence of droughts and floods because of changing rainfall patterns caused by climate change would be detrimental to the surface and groundwater recharge and also pose a great challenge to water security.

3.3 Effect of Temperature on Mean Rainfall across Agro Climatic Zones in Karnataka

A simple graphical representation of both climate variables temperature and rainfall showed that , the rise in temperature has negative effect on rainfall pattern (Fig. 12).It was noticed that , the increase in rainfall has seen in hilly zone .While all other zones showed inverse relationship of rainfall with temperature rise over the 40 years.
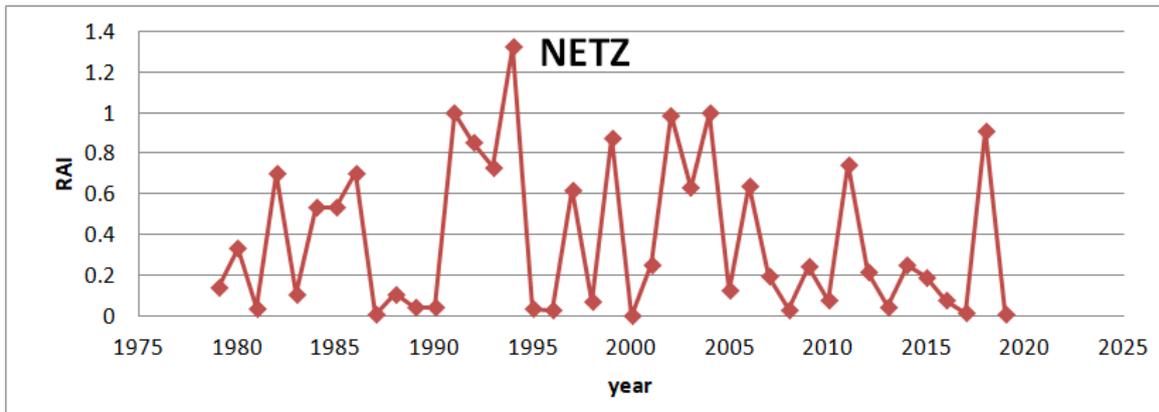
Fig. 1. Rainfall Anomaly index of ACZ I-North Eastern Transition Zone
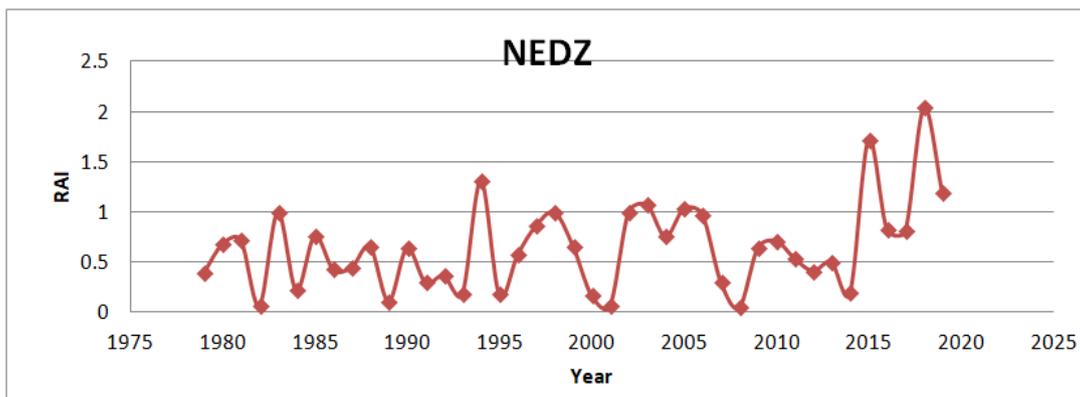
Fig. 2. Rainfall Anomaly index of ACZ II-North Eastern Dry zone
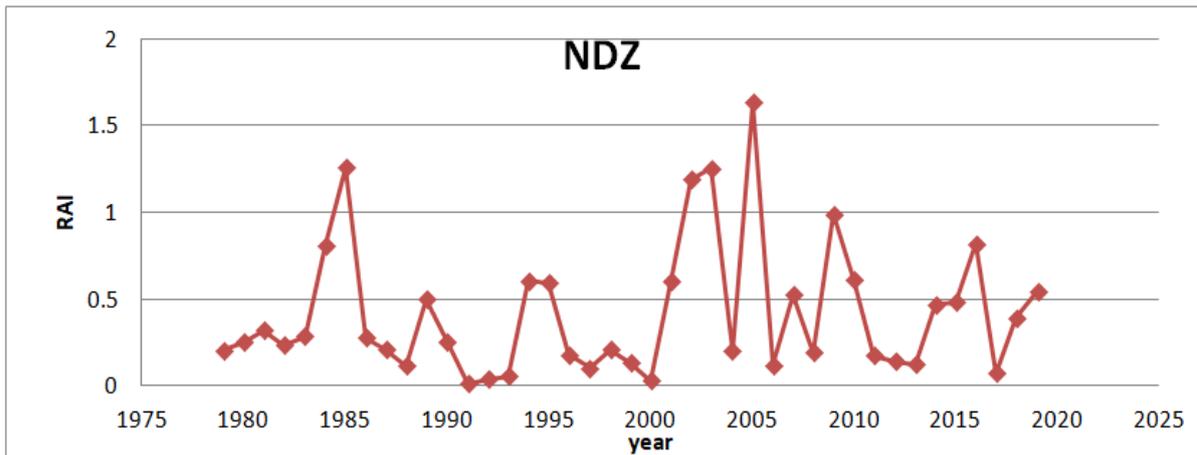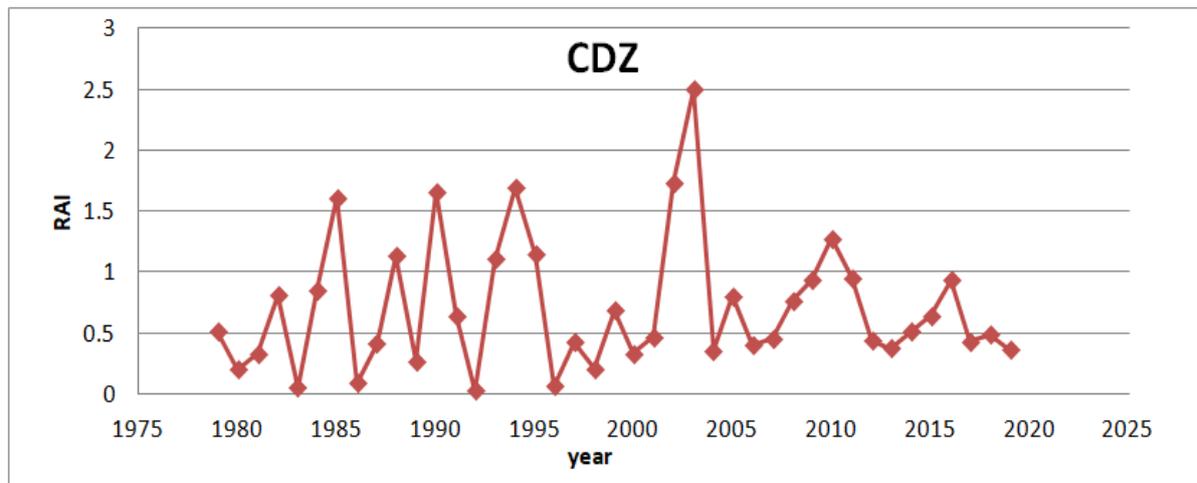
Fig. 3. Rainfall Anomaly index of ACZ III-Northern Dry Zone

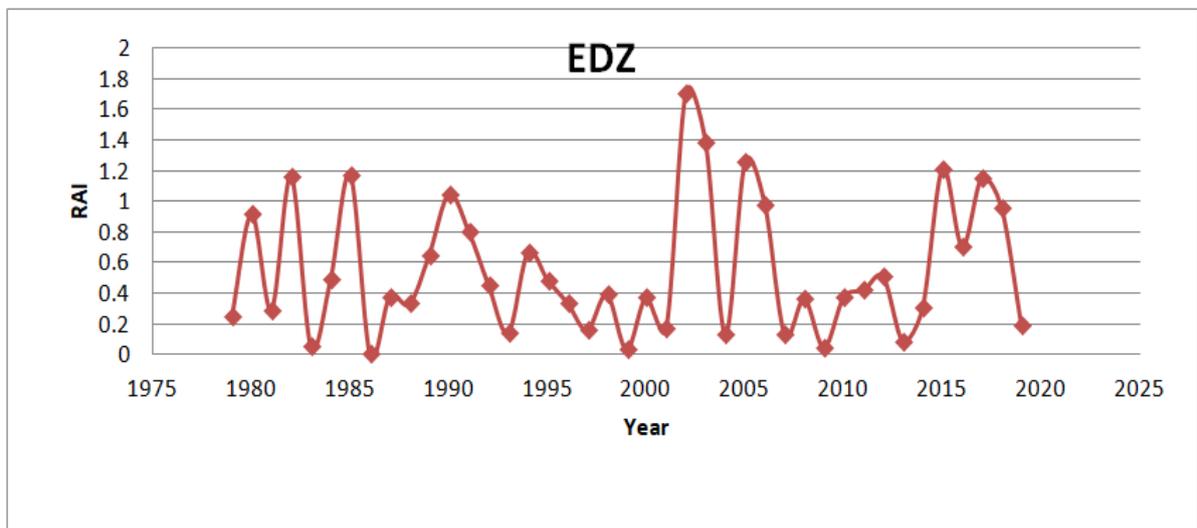**Fig. 4. Rainfall Anomaly index of ACZ IV-Central Dry Zone**

Fig. 5. Rainfall Anomaly index of ACZ V-Eastern Dry Zone
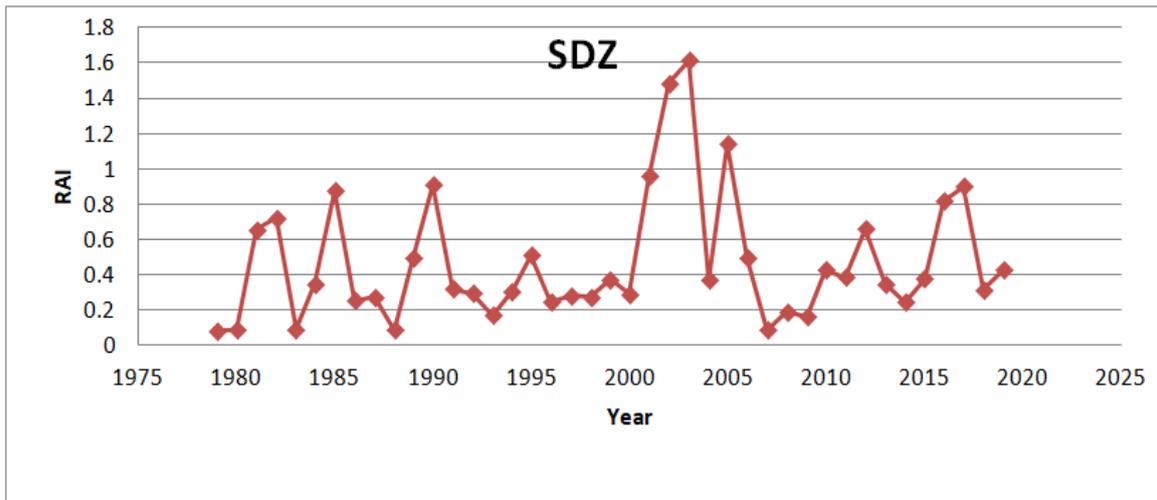
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Fig. 6. Rainfall Anomaly index of ACZ VI-Southern Dry Zone
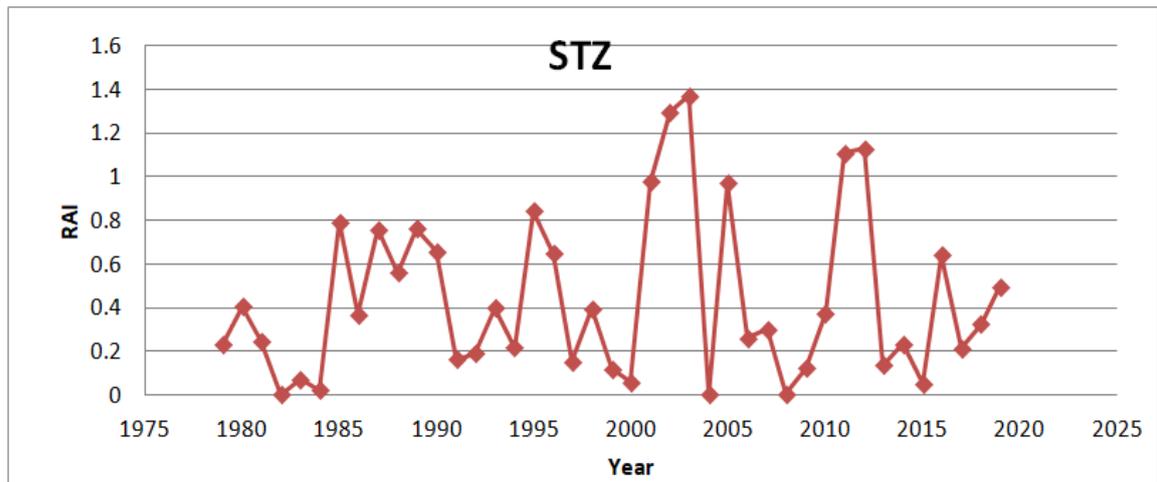

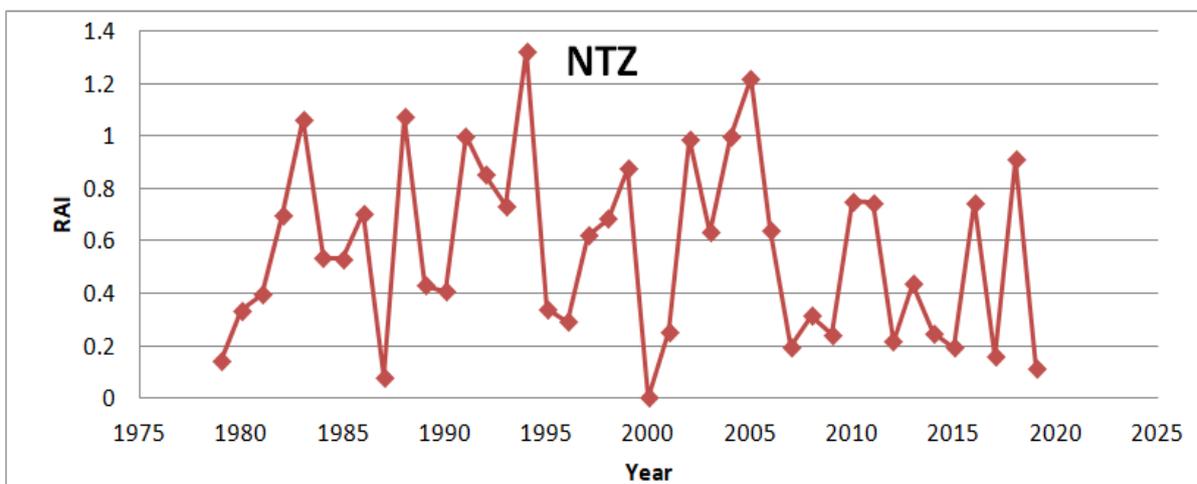**Fig. 7. Rainfall Anomaly index of ACZ VII-Southern Transition Zone**

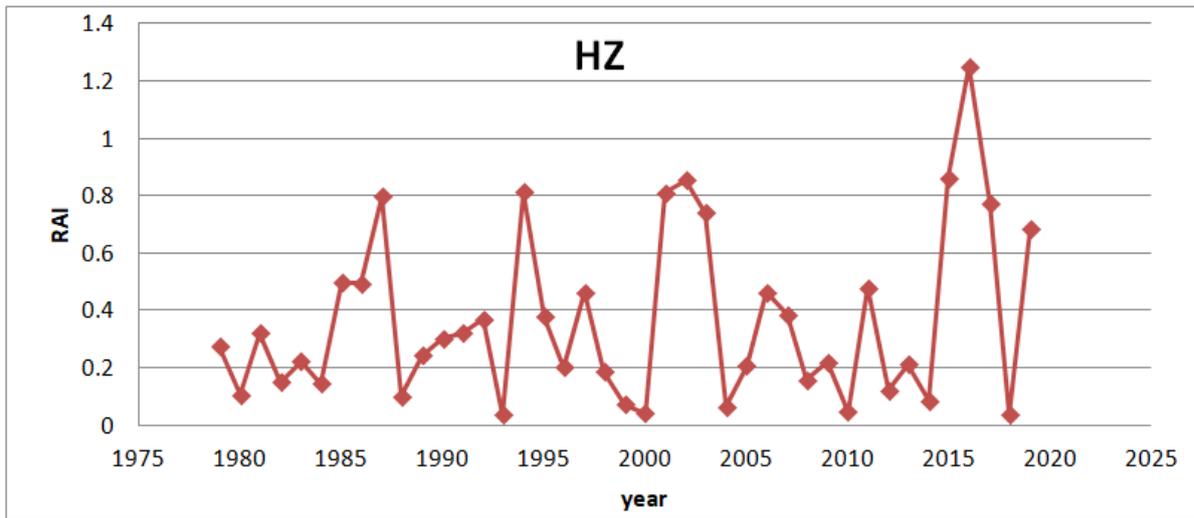**Fig. 8. Rainfall Anomaly index of ACZ VIII-Northern Transition Zone**
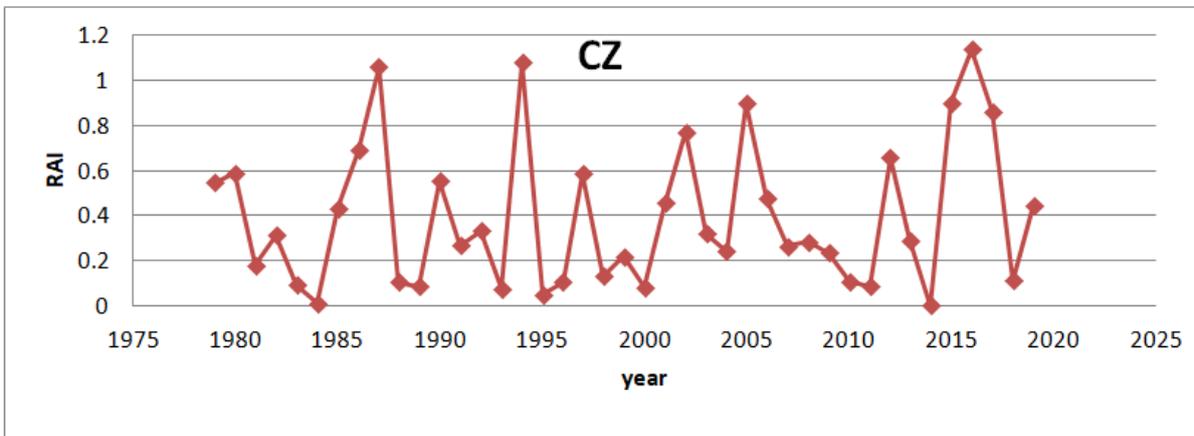
Fig. 9. Rainfall Anomaly index of ACZ IX-Hilly Zone

Fig. 10. Rainfall Anomaly index of ACZ X-Coastal Zone

	NETZ	EDZ	NEDZ	NTZ	CDZ	CZ	HZ	NDZ	SDZ	STZ
2015	0.193	1.213	1.714	0.193	0.641	0.901	0.863	0.483	0.374	0.052
2016	0.077	0.705	0.821	0.747	0.932	1.135	1.250	0.818	0.817	0.640
2017	0.016	1.153	0.811	0.159	0.430	0.860	0.773	0.070	0.900	0.213
2018	0.912	0.953	2.034	0.912	0.490	0.115	0.034	0.393	0.312	0.325
2019	0.012	0.195	1.190	0.114	0.366	0.445	0.682	0.545	0.423	0.497
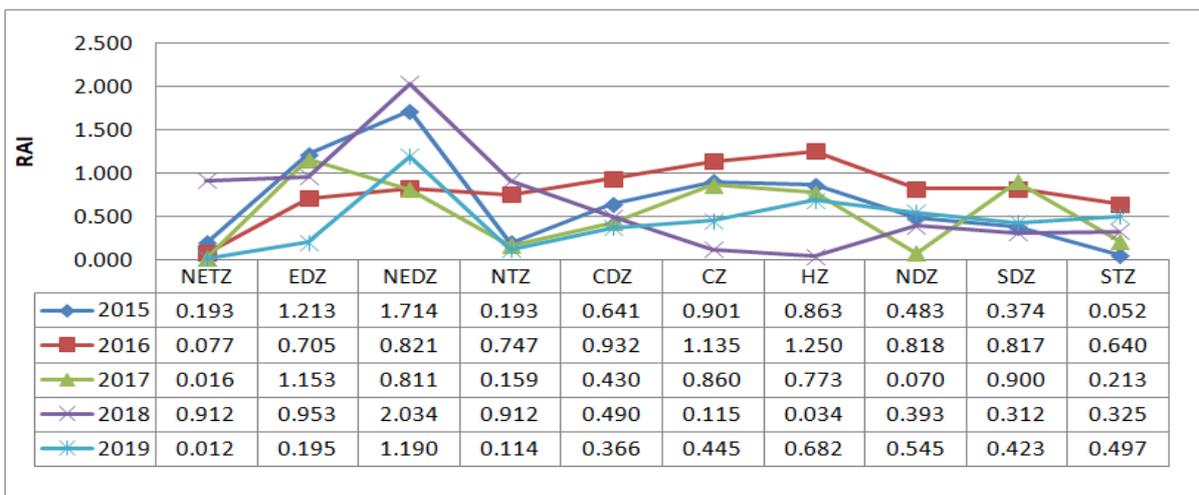
Fig. 11. Rainfall Anomaly index across Agro climatic zones for the period of 2015-2019
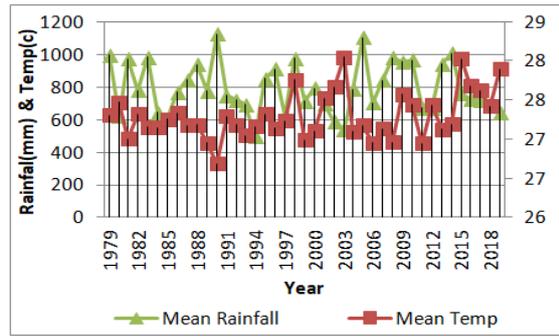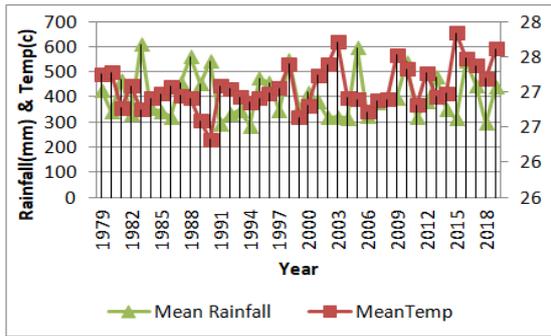
Fig. 12 a):ACZ –I -North Eastern Transition Zone

Fig. 12 b) ACZ-II- North Eastern Dry zone
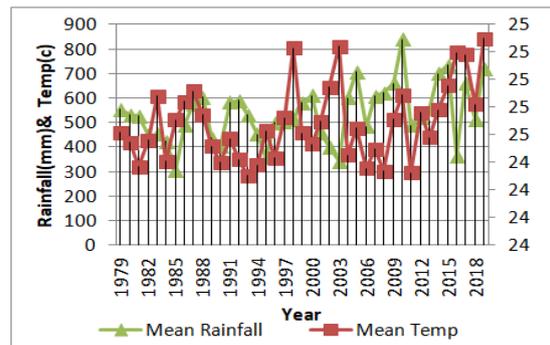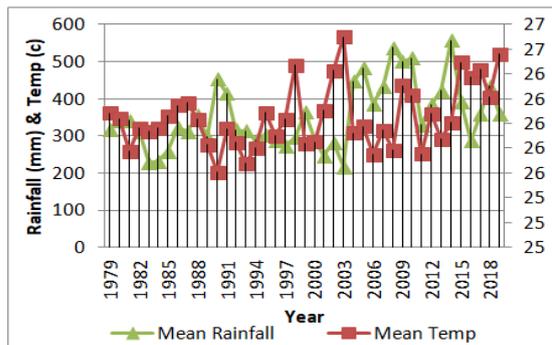
Fig. 12c)   ACZ -III   Northern Dry zone

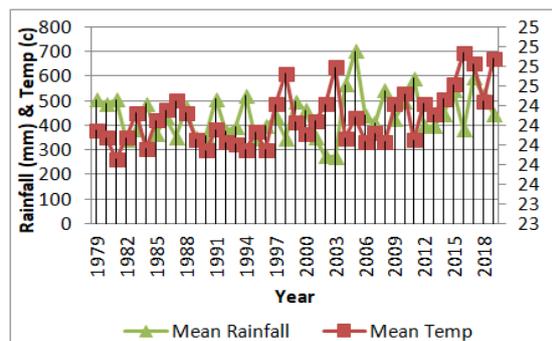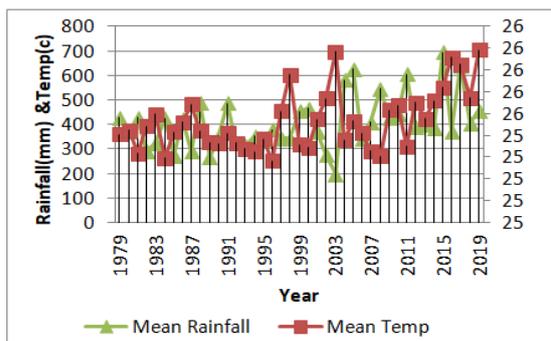
Fig. 12 d) ACZ-IV   Central Dry Zone

Fig. 12 e)   ACZ-V   Eastern Dry Zone

Fig. 12 f) ACZ-VI Southern dry zone
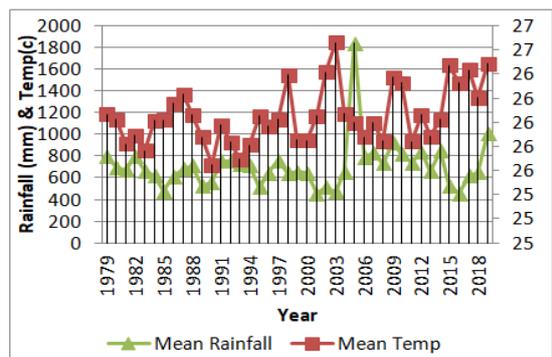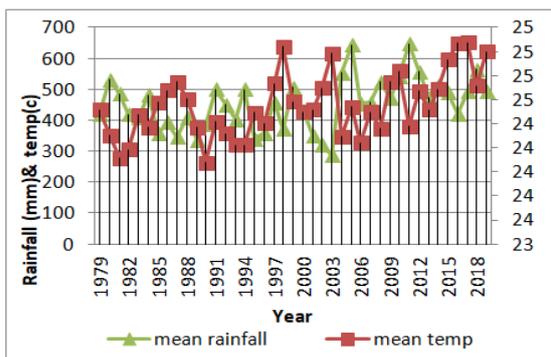

Fig. 12 g) ACZ-VII Southern Transition Zone

Fig. 12h) ACZ-VIII Northern Transition Zone
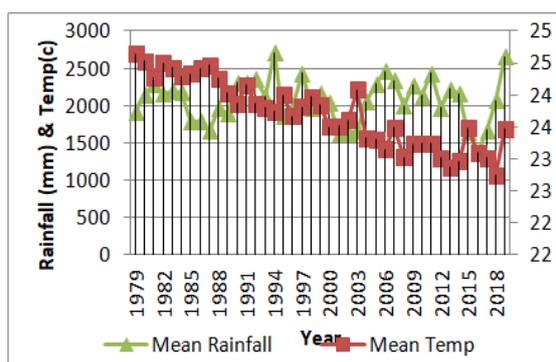
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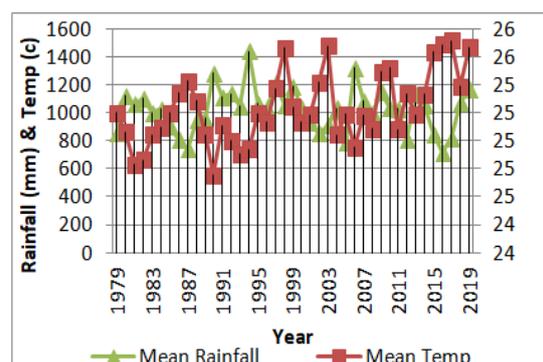
Fig. 12 i) ACZ-IX Hilly Zone   Fig. 12 j) ACZ-X Coastal zone

Fig. 12. Temperature and Rainfall in Different Agro climatic zones in Karnataka (1978-79 to 2018-19)

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4. CONCLUSION

Karnataka has warmed over the years and that climate variability has occurred for sure during the four decadal study period 1979-2019 as there was increased trend in both minimum temperature and maximum temperature for about 40 years. Through Rainfall Anomaly Index ,it was noticed that, all zones are falls in category of dry zone with range of 0.2 to 0.4 and further , North Eastern Transition Zone was noted RAI of below 0.2 to near zero. Therefore, NETZ was needed to have depth analysis at ground level to find about the impact of climate change on agriculture, socio economic condition of farmers and suggesting measures to overcome the adverse impacts of climate variability on agricultural productivity.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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