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Climate variability and its impact on cropping pattern and agricultural GDP in central dry zone of Karnataka, India

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सार – कृषि प्रणालियों पर जलवायु परिवर्तनशीलता के प्रभावों को समझना वर्तमान समय की महत्वपूर्ण आवश्यकता है। इसलिए कर्नाटक के जलवायु की दृष्टि से सबसे संवेदनशील जिले, अर्थात चित्रदुर्ग में 120 किसानों के प्राथमिक डेटा और वर्षा पैटर्न (1901-2015), तापमान (1971-2015), फसलों के क्षेत्र, उत्पादन और उत्पादकता पर द्वितीयक डेटा (1956-2011) का अध्ययन किया गया। समरूपता परीक्षण, मार्कोव चेन विश्लेषण और स्वसमाश्रयी त्रुटि सुधार मॉडल जैसे उपकरणों का उपयोग करके डेटा का विश्लेषण किया गया। समरूपता परीक्षण के अनुसार वार्षिक वर्षा और वर्षा के दिनों (≥2.5 मिमी) की दीर्घ अवधि की प्रवृत्ति में कोई बदलाव या अंतराल नहीं था। जबकि कुल गैर-वर्षा दिनों (<2.5 मिमी) में वृद्धि की प्रवृत्ति देखी गई। दैनिक अधिकतम (1.22 डिग्री सेल्सियस) और न्यूनतम (1.36 डिग्री सेल्सियस) तापमान दोनों में वृद्धि हुई है। 1990 के दशक के बाद जलवायविक प्राचलों की दीर्घकालिक प्रवृत्ति में बदलाव सबसे प्रमुख था। मार्कोव चेन विश्लेषण ने पानी से अधिक सिंचित फसलों जैसे गन्ना और वर्षा आधारित सुपारी की फसलों में संक्रमण पर प्रकाश डाला है। इस जिले के कृषि सकल घरेलू उत्पाद पर दक्षिण-पश्चिमीमॉनसून वर्षा की मात्रा का सकारात्मक प्रभाव स्वसमाश्रयीत्रुटि संशोधन मॉडल से साबित हुआ। जलवायु परिवर्तनशीलता और जलवायु परिवर्तन अपरिहार्य हैं और विशेष रूप से वर्षा क्षेत्रों में किसानों के लिए कृषि से होने वाली आय खोने की समस्या पैदा करते हैं। वर्षा पर आश्रित किसानों को रियायती कीमतों पर कृषि संबंधी सहायता प्रदान की जानी चाहिए और कृषि कार्यों को जारी रखने के लिए आय में सहयोग के साथ सहायता प्रदान की जानी चाहिए। जलवायु परिवर्तनशीलता के प्रति किसानों की परिस्थितियों में सुधार के लिए वनीकरण, जल संचयन संरचनाओं, भूजल पुनर्भरण तकनीकों जैसी मौजूदा योजनाओं के प्रभावी कार्यान्वयन को बढ़ावा देने की आवश्यकता है।

ABSTRACT. Understanding effects of climate variability on agricultural systems is an vital present need. Hence a study was carried out in climatically most vulnerable district of Karnataka, *i.e.*, Chitradurgausing primary data from 120sample farmers and secondary data on rainfall pattern (1901-2015), temperature (1971-2015), area, production and productivity of crops (1956-2011). The data was analysed using tools like homogeneity test, markovchain analysis and autoregressive error correction model. As per homogeneity test there were no shifts or breaks in the long-term trend of annual rainfall and in rainy days (≥2.5 mm).Whereas an upward shift in total non -rainy days (< 2.5 mm) was observed. Both daily maximum (1.22 °C) and minimum (1.36 °C) temperature has increased. The shift in long-term trend of climate parameters was most prominent after 1990's. Markov chain analysis highlighted transition from water intensive irrigated crops such as sugarcane and areca nut to rainfed crops. Positive impact of quantum of south-west monsoon rainfall on the district agricultural gross domestic product was proved from autoregressive error correction model. Climate variability and climate change are inevitable and pose problem of losing agricultural income for the farmers particularly in the rainfed areas. The rainfed farmers should be provided agricultural inputs at subsidized prices and assisted with the income support to continue the agricultural practices. To improve the farmers' resilience to climate variability an effective implementation of existing schemes pertaining to afforestation, water harvesting structures, ground water recharge techniques need to be given boost.

Key words – Climate variability, Autoregressive error correction model, Cropping pattern, Agricultural GDP and markov chain analysis.

1. Introduction

The climate change and climate variability topic has gained a lot of attention from researchers and academicians all around the globe because of its ill effects on our ecosystem, food production and on human livelihood. Agriculture being continuously and directly affected by precipitation and temperature, this sector is considered as one of the most climate-sensitive sectors. Climate change and climate variability pose a great risk to the world's agricultural and natural resource systems which are already finding it difficult to cope with the growing food demand driven by population growth and the higher purchasing power in developing countries.

The state of atmosphere at a particular place and time is weather and the average weather is called climate. There is increase in global average surface temperature by 2 °C increase since 1880-1990 and ten warmest years in the last century have all occurred since 2005 and seven of them have occurred just since 2014 (Lindsey and Dahlman, 2021). Global climate change is likely to increase the incidence of natural hazards, including the variability of rainfall, temperature and occurrences of climatic shocks (Anonymous, 2014). The semi-arid regions are among those areas which are most likely to experience increased climatic stress (Anonymous, 1990). As a consequence, food availability, access, utilization and stability are affected. Risks are unevenly distributed and are generally greater for poor people and communities with in every country at all levels of development. (Anonymous, 2014). Thus, climate change will amplify existing risks and also create new risks for nature as well for human beings.

The impact of climate variability will affect both demand and supply side of farms. Many scientific studies predicted that due to climate change, amount of precipitation and its distribution has been affected. Significant impact would be on agriculture, as water supply and its availability get disturbed, soil fertility would go down due to reduced soil moisture and overall productivity would decline (Downing, 1992). Climate change causes shift in cropping patterns where it directly affects the food production and food security. The induced change in cropping pattern due to climate variability may lead to reduced farm income. Consequently, lowers rural demand which in turn will lead to economic slowdown, make poverty reduction efforts more challenging, erode food security of poor farmers, prolong prevailing poverty traps and create new poverty traps (Anonymous, 2014). In this context, present study analyses the temporal variability of key climatic parameters like rainfall, temperature and number of rainy days; influence of rainfall variability on cropping pattern and economic impact of climate variability on agricultural production in Karnataka.

2. Data and methodology

The present study was taken in Chitradurga district of Karnataka state, India which is a drought prone. Hence this district was purposively selected for the study. Study involves both primary and secondary source data. Daily rainfall (1901-2015) and temperature (1971-2015) data was collected from India Metrological Department (IMD).

The data on area, production and productivity (1956-2011) and agricultural GDP (1990-2011) was collected from Directorate of Economics and Statistics, Bengaluru. Later agricultural GDP data was converted to constant price using wholesale prices.

2.1. *Temporal variability of climate parameters*

To find out the pattern and behaviour of climatic variables, *viz*., annual rainfall, seasonal rainfall, monsoon months rainfall, individual month rainfall, number of rainy days for monsoon months and individual months, daily, seasonal and individual monsoon months maximum and minimum temperatures were subjected to homogeneity tests.

2.2. *Identification of structural break in the time series*

Following homogeneity tests were used to examine the exact shift or break in the time series data with null hypothesis (H_0) being data is homogeneous and alternate hypothesis (H_a) being there is a break in the time series.

(*i*) *Pettitt's test* : It is non-parametric test and widely used to find out single break point in continuous data. The ranks from $t_1...t_n$ of the $Y_1...Y_n$ are used to calculate the statistics (Pettitt, 1979).

$$X_k = 2\sum_{i=1}^{k} t_i - r(n+1),\ X_k = \underset{1\le k\le n}{Max}|X_k|,$$

$$X_{cj} = \sqrt{\left|\frac{-\ln\alpha\left(n^3+n^2\right)}{6}\right|}$$

X_{cj} is the critical value for a probability level α and if the value of X_k is greater than X_{cj} at specified level of α, the null hypothesis will be rejected.

(*ii*) *Standard normal homogeneity test (SNHT)* : The test is more sensitive to the breaks in the earlier part and later part of the datasets. Statistic $T_{(k)}$ compares the mean of the first k years of the record with that of the last (n - k) years. $T_{(k)} = kZ_1^2 + (n-k)Z_2^2$

$$Z_1 = \frac{1}{k}\sum_{i=1}^{n}\left[\frac{(Y_i - \overline{Y})}{s}\right]$$

$$Z_2 = \frac{1}{n-k}\sum_{i=k+1}^{n}\left[\frac{(Y_i - \overline{Y})}{s}\right]^2$$

$$s^2 = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \overline{Y})^2$$

The $T_{(k)}$ reaches the maximum near the year k if the break is located at the year k. The test statistic T_o is defined as $T_o = \underset{1\leq k\leq n}{Max}\ T_{(k)}$

(*iii*) *Buishand test* : The test is also more sensitive to the breaks in the earlier part and later part of the datasets. In this test, the adjusted partial sums are defined as,

$$s_0^* = 0; \quad s_j^* = \sum_{i=1}^{k}(Y_i - \overline{Y}), \qquad k = 1, 2, \ldots, n$$

When a series is homogeneous, the values of S_k will fluctuate around zero. If a break is present in year, then S_k* reaches a maximum (negative shift) or minimum (positive shift) near the year $k = n$. The significance of the shift can be tested with the rescaled adjusted range R, which is the difference between the maximum and minimum of the S_k* values scaled by the sample standard deviation. Q = max $|s^*|$ and R= (max S_k* - min S_k*) / s Buishand gives critical values for $R/\sqrt{n}$ (Buishand, 1982).

Structural changes in area under crops : Markov chain analysis (MCA) is used to estimate the value of transitional probability matrix (TPM) Q. The element Q_{nm} of this matrix denotes the probability of shift of cropped area from crop n to crop m with time t. The diagonal values of Q_{nm} quantify the area under crop retained by the same crop. The diagonal element denotes the strength of the crop to retain in the cultivation in that time period.

The MCA was carried out to examine shifts in cropping pattern (1998-2011). The cultivation of each individual crop is considered to be a random variable which depended only on its previous cultivation area. It can be denoted algebraically as,

$$E_{mt} = \sum_{i=1}^{r}\ [E_{nt-1}] * Q_{nm} + e_{mt}$$

$$0 \leq Q_{nm} \leq 1$$

$$\sum_{i=1}^{n} Q_{nm} = 1$$

where,

E_{mt}	=	Shifting of cropping area among the crops during the year t to m crop
E_{nt-1}	=	Shifting of crops to n crop during the year t-1
Q_{nm}	=	Probability that cropping area will shift from n crop to m crop
e_{mt}	=	Error-term which is statistically independent of E_{nt-1}
r	=	Number of crops grown

The expected cropped area of each crop during period t was obtained by multiplying the cropped area of the crop in the previous period (t-1) with the TPM. The TPM is estimated in the linear programming (LP) frame work.

Autoregressive Error Correction Model (AEC) : To find out the impact of climatic variables on per hectare agricultural GDP, AEC model was employed. AEC model takes care of autocorrelation in return and the variance in error which reflect the true value by using this model. To remove the effect of inflation on agricultural GDP the series was expressed in 2004-05 prices. The regression model employed can be denoted as,

ln district agricultural GDP = f (ln pre-monsoon, ln South-west monsoon, ln North-east monsoon, ln Maximum temperature, ln Minimum temperature)

3. Results and discussion

3.1. *Temporal variability of key climatic parameters*

The temporal variability of climate parameters such as rainfall and temperature are presented in this section. Amount of rainfall and rainy days variability is analysed using annual, monsoon (June to September), individual

TABLE 1

Homogeneity test to detect the shift in intensity of rainfall

Particulars	Rainfall days with less than 2.5 mm			Rainy days with more than or equal to 2.5 mm			Rainy days between 2.51 to 5.00 mm			Rainy days between 5.1 to 7.50 mm		
	Pettitt's test	SNHT	Buishand's test	Pettitt's test	SNHT	Buishand's test	Pettitt's test	SNHT	Buishand's test	Pettitt's test	SNHT	Buishand's test
T	1968	2009	1974	1968	2003	1973	1969	1969	1969	1955	1995	1968
p-value (Two-tailed)	< 0.0001	0.000	< 0.0001	0.025	0.009	0.017	0.000	< 0.0001	< 0.0001	0.003	0.002	0.001

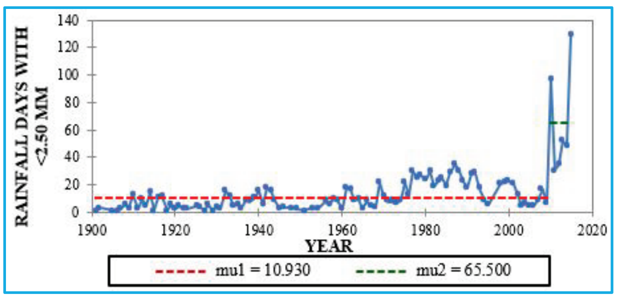

Fig. 1. Non-rainy days with less than 2.50 mm rainfall per day

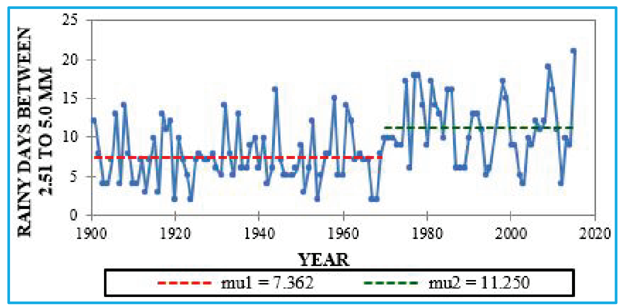

Fig. 3. Rainy days with rainfall between 2.51 to 5.0 mm rainfall per day

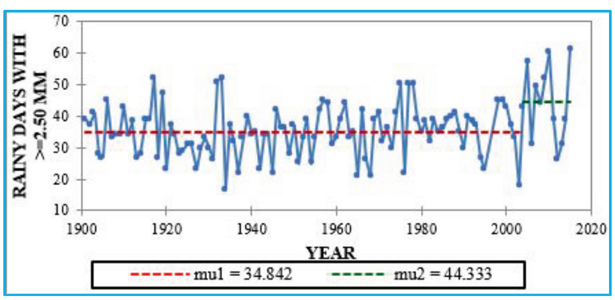

Fig. 2. Rainy days with more than or equal to 2.50 mm rainfall per day

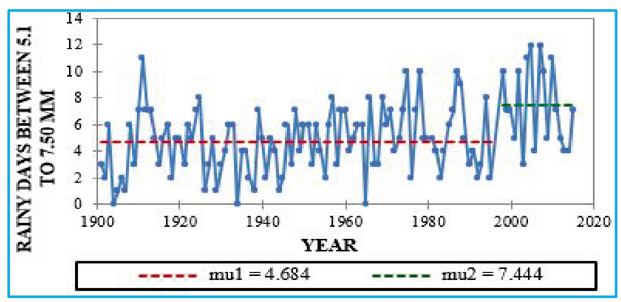

Fig. 4. Rainy days with rainfall between 5.1 to 7.50 mm rainfall per day

months of monsoon series data. Similarly daily maximum and minimum temperatures over the years, pre-monsoon (January to May), South-West monsoon (June to September), North-East monsoon (October to December) seasons and individual months during SW monsoon season were analysed. SNHT test results were used for explanation since it takes into account of normal distribution in the analysis. Statistically significant results are presented and interpreted here under separate headings.

(*i*) *Total rainfall* : There exists no change or shift in long-term trend of rainfall in annual, monsoon season and individual months of monsoon series. Jangra & Singh (2011) also reported that there is no change in quantity of annual rainfall.

(*ii*) *Rainy days per year* : The analysis of rainy days for all months is presented in Table 1.The results indicated that non-rainy days per year increased from 10.93 days to 65.50 days since 2009 (Fig. 1). The rainy days more than or equal to 2.5 mm rainfall has increased from 34.84 to 44.33 days since 2003 (Fig. 2). The rainy days ranging from 2.51 to 5.00 mm rainfall per day also found increased from 7.36 to 11.25 days (Fig. 3) since 1969. The high intensity rainfall ranging between 5.1 to 7.5 mm per day (Fig. 4) also found increased from 4.68 to 7.44 days from 1995.

TABLE 2

Homogeneity test to detect the shift in intensity of rainfall during south-west monsoon months (June to September)

Particulars	Rainfall days with less than 2.5 mm			Rainy days with more than or equal to 2.5 mm			Rainy days between 2.51 to 5.0 mm			Rainy days between 5.1 to 7.5 mm
	Pettitt's test	SNHT	Buishand's test	Pettitt's test	SNHT	Buishand's test	Pettitt's test	SNHT	Buishand's test	Buishand's test
T	1973	2009	1974	1955	2003	1973	1969	1970	1970	1968
p-value (Two-tailed)	< 0.0001	0.000	< 0.0001	0.032	0.040	0.028	< 0.0001	< 0.0001	< 0.0001	0.019

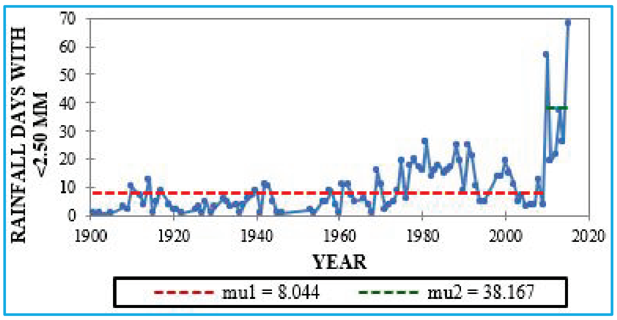

Fig. 5. Non-rainy days during south-west monsoon months (rainfall less than 2.50 mm per day)

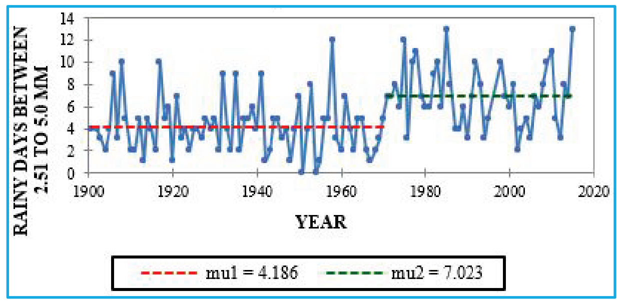

Fig. 7. Rainy days during south-west monsoon months with rainfall between 2.51 to 5.0 mm per day

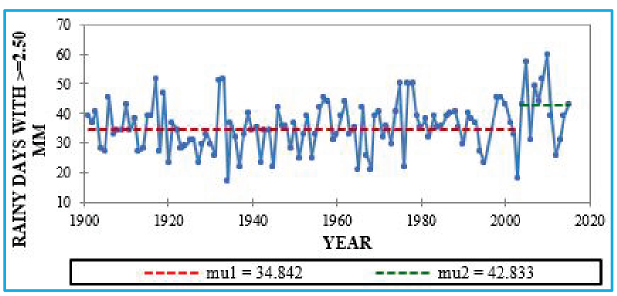

Fig. 6. Rainy days during south-west monsoon months with rainfall more than or equal to 2.50 mm per day

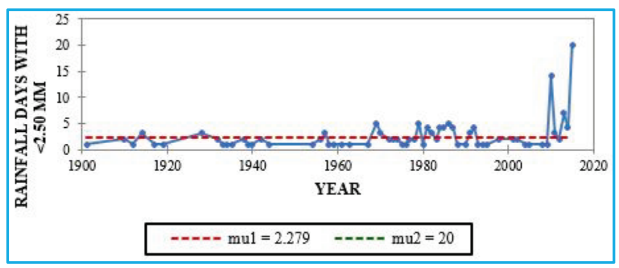

Fig. 8. Non-rainy days during June month with less than 2.50 mm per day

Even though there is no significant shift in the total annual rainfall, but quantity of rainfall received per day has seen significant shift. The rainfall received per day with less than 2.5 mm, more than or equal to 2.5 mm, 2.51 to 5.00, 5.1 to 7.5 mm were increased significantly from the normal long-term trend. Since the rainfall received per day with more than 5.0 mm has increased indicating that intensity of the rainfall has increased. This enables to accept the hypothesis that the rainfall pattern has changed from low intensity to high intensity. Rainfall with high intensity could hinder the crop growth and development (Dourte *et al.*, 2015; Rani *et al.*, 2014 and Samui *et al.*, 2013).

(*iii*) *Rainy days during monsoon* : The analysis of rainy days during SW monsoon is presented in Table 2. The results obtained from homogeneity test indicated that non-rainy days has increased from 8.04 to 38.17 days since 2009 (Fig. 5); the rainfall interval with more than or equal to 2.5 mm per day rainy days has increased from 34.84 to 42.83 days (Fig. 6) since 2003. Similarly, the rainy days between 2.51 to 5.00 mm per day also found increased from 4.17 to 7.02 days since 1970 during monsoon season (Fig. 7). The rainy days with more than 5.00 mm also found increased during monsoon months. These findings corroborate with the results of the Dourte *et al.* (2015); Rani *et al.* (2014) and Samui *et al.* (2013).

TABLE 3

Homogeneity test to detect the shift in intensity of rainfall for individual monsoon months

Month	Particulars	Rainfall days with less than 2.5 mm			Rainy days between 2.51 to 5.0 mm		
		Pettitt's test	SNHT	Buishand's test	Pettitt's test	SNHT	Buishand's test
June	t	1967	2014	2009	1970	1970	1970
	p-value*	0.009	0.002	0.003	0.029	0.039	0.011
July	t	1973	2009	1976	-	-	-
	p-value*	< 0.001	< 0.0001	< 0.0001	-	-	-
August	t	1973	1974	1974	1973	1981	1981
	p-value*	< 0.0001	0.000	< 0.0001	0.000	0.001	0.000
September	t	1974	2009	1974	-	-	-
	p-value*	0.000	0.036	0.003	-	-	-

Note: *Two-tailed

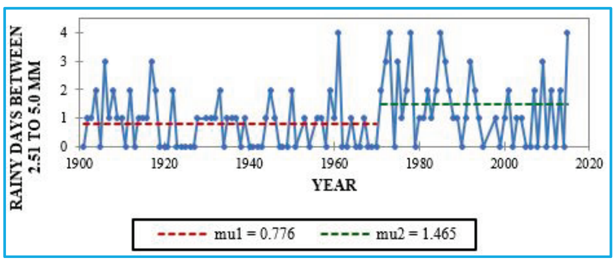

Fig. 9. Rainy days during June month with rainfall between 2.51 to 5.0 mm

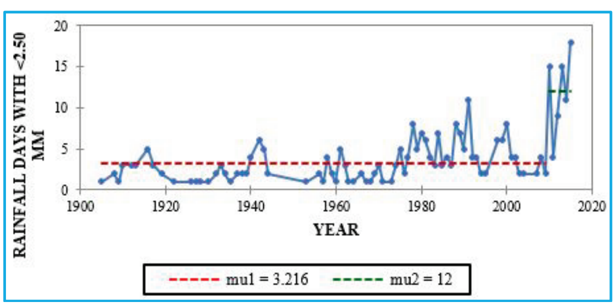

Fig. 10. Non-rainy days during July month with less than 2.50 mm per day

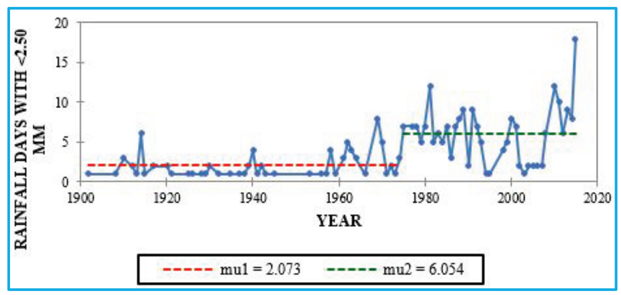

Fig. 11. Non-rainy days during August month with less than 2.50 mm per day

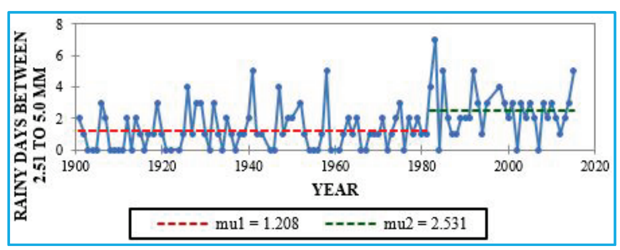

Fig. 12. Rainy days during August month with rainfall between 2.51 to 5.0 mm per day

(*iv*) *Rainy days during individual months of SW monsoon* : The results of homogeneity test for rainy days during individual months of SW monsoon is presented in Table 3 and graphically represented in Figs. 8 to 13.The rainfall with less than 2.5 mm per day found to be increased from 2.28 to 20.0 days since 2014 in June, from 3.22 to 12.00 days since 2009 in July, from 2.07 to 6.05 days since 1974 in August and from 2.22 to 7.33 days since 2009 in September. The increase in the number of rainy days during September month may hinder the harvesting activities of short duration crops (Rani *et al.*, 2014 and Samui *et al.*, 2013).

(*v*) *Temperature* : The results of homogeneity test pertaining to temperature of Chitradurga are presented in Table 4. The results revealed that the daily maximum

TABLE 4

Homogeneity test to detect the shift in daily temperature

Particulars	Maximum temperature			Minimum temperature		
	Pettitt's test	SNHT	Buishand's test	Pettitt's test	SNHT	Buishand's test
t	21/01/2002	10/02/2010	21/01/2002	13/03/1997	16/02/2011	12/3/1997
p-value (Two-tailed)	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

TABLE 5

Homogeneity test to detect the shift in temperature during south-west monsoon period

Particulars	Maximum temperature			Minimum temperature
	Pettitt's test	SNHT	Buishand's test	SNHT
T	1994	2009	2007	2010
p-value (Two-tailed)	0.001	0.000	0.000	0.013

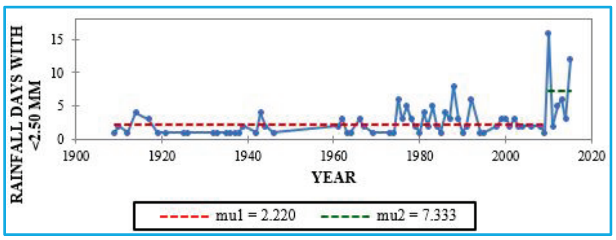

Fig. 13. Non-rainy days daring during September month with less than 2.50 mm per day

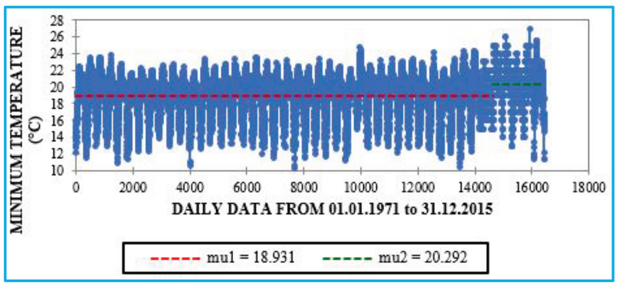

Fig. 15. Daily minimum temperature (°C)

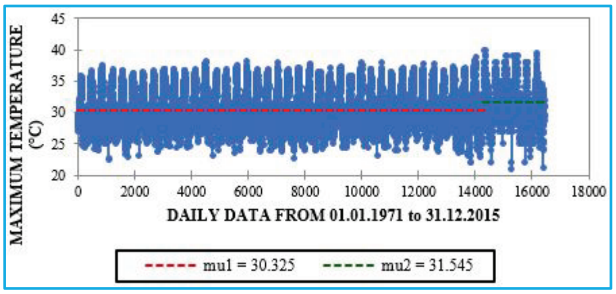

Fig. 14. Daily maximum temperature (°C)

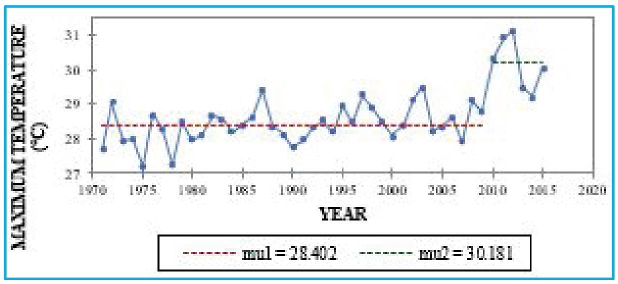

Fig. 16. Maximum temperature (°C) during south-west monsoon period

temperature had increased from 30.32 °C to 31.54 °C (Fig. 14) from 10/02/2010 whereas it is found that the daily minimum temperature also increased from 18.93 °C to 20.29 °C from 16/02/2011 (Fig. 15). So the increase in the maximum and minimum temperatures in the district to the tune of 1.22 °C and 1.36 °C respectively. Studies by Kumar *et al.* (2014), Singh *et al.* (2014) and Jangra & Singh (2011) also reported a gradual increase in temperature in other context.

The homogeneity test for south-west monsoon period was conducted and presented in Table 5. The results revealed that the maximum and minimum temperatures increased from 28.40 °C to 30.18 °C (Fig. 16) and from 20.10 °C to 20.96 °C (Fig. 17). The shift in temperature was from 2009 and 2010 for maximum and minimum temperatures respectively. The increases in maximum and minimum temperatures were about 1.78 °C and 0.86 °C for the south-west monsoon period in Chitradurga district.

TABLE 6

Homogeneity test to detect the shift in temperature in individual monsoon months

Particulars	July	August		September		
	Pettitt's test	Pettitt's test	SNHT	Pettitt's test	SNHT	Buishand's test
T	1993	1997	2007	1997	2010	2007
p-value (Two-tailed)	0.044	0.030	0.017	0.006	< 0.0001	0.003

TABLE 7

Homogeneity test to detect the shift in minimum temperature in individual monsoon months

Particulars	June			July			August			September	
	Pettitt's test	SNHT	Buishand's test	Pettitt's test	SNHT	Buishand's test	Pettitt's test	SNHT	Buishand's test	SNHT	Buishand's test
t	1994	2008	1994	1995	2009	2001	1992	2008	2007	2010	2009
p-value (Two-tailed)	0.017	0.004	0.009	0.002	0.000	0.001	0.000	< 0.0001	0.000	0.004	0.039

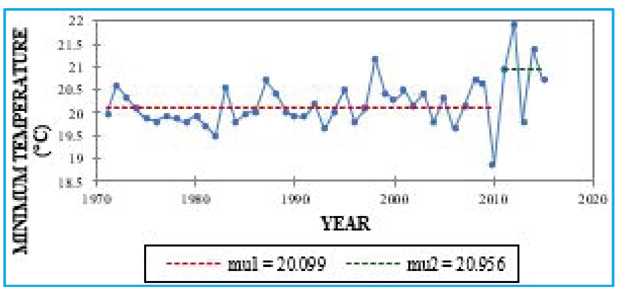

Fig. 17. Minimum temperature (°C) during south-west monsoon period

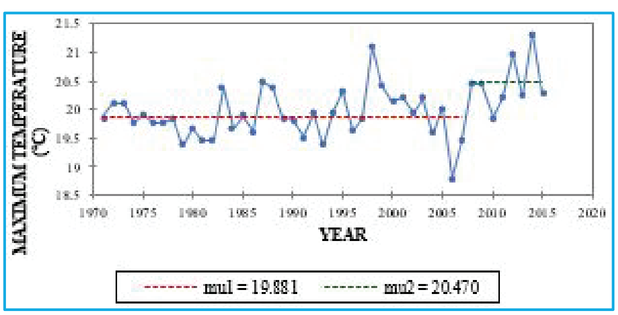

Fig. 18. Maximum temperature (°C) during August month

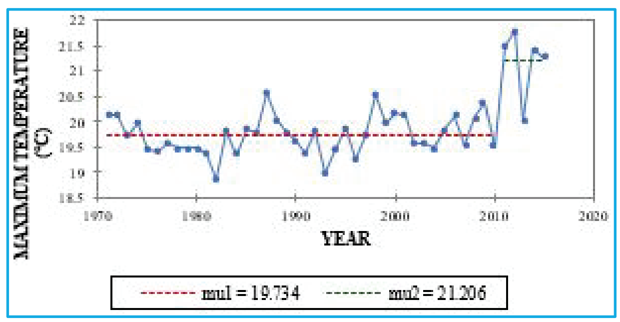

Fig. 19. Maximum temperature (°C) during September month

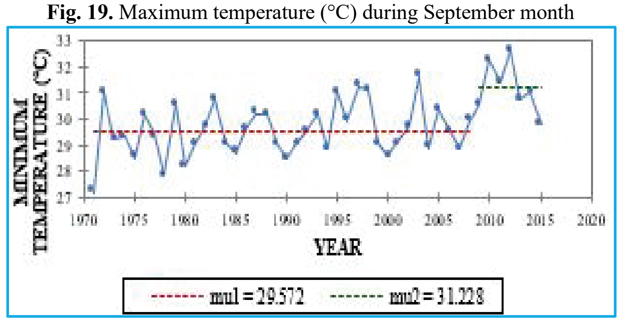

Fig. 20. Minimum temperature (°C) during June month

The homogeneity tests for maximum temperature among individual months during monsoon period (June to September) were carried out and the results are presented in Table 6. The results revealed that the maximum temperature in August and September months had increased from 19.88 °C to 20.47 °C (Fig. 18) and from 19.73 °C to 21.21 °C (Fig. 19) respectively during the period 2007 and 2010.

TABLE 8

Transitional Probability matrix of cropping pattern in Chitradurga district (1998-2011)

1998-2000 TE (ha.) / 2009-2011 TE (ha.)	Share in area (%)	Crop	12623.00	37556.33	41931.67	159795.00	34187.33	18999.00	1393.67	7980.33	37325.33	63810.67	8587.67	7784.67	6225.00	15124.33	16973.67	28252.17
			2.51	7.48	8.35	31.83	6.81	3.78	0.28	1.59	7.43	12.71	1.71	1.55	1.24	3.01	3.38	5.63
			Rice	Sorghum	Maize	Groundnut	Sunflower	Cotton	Sugarcane	Areca nut	Coconut	Ragi	Fox tail millet	Tur	Bajra	Onion	Horse gram	Others
10339.67	2.10	Rice	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
23263.33	4.72	Sorghum	0.00	0.00	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.01	0.01	0.00	0.03	0.01
97073.00	19.69	Maize	0.00	0.00	0.58	0.00	0.00	0.04	0.00	0.06	0.03	0.00	0.00	0.03	0.00	0.07	0.00	0.18
124956.00	25.35	Groundnut	0.03	0.00	0.00	0.43	0.03	0.08	0.00	0.00	0.12	0.14	0.00	0.03	0.01	0.06	0.06	0.03
18842.33	3.82	Sunflower	0.00	0.04	0.00	0.06	0.71	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.03	0.00	0.00
15676.00	3.18	Cotton	0.21	0.54	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.01
23.72	0.00	Sugarcane	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.78	0.00	0.00	0.00	0.00	0.00	0.00
16379.00	3.32	Areca nut	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52
42406.00	8.60	Coconut	0.00	0.00	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24
48911.00	9.92	Finger millet	0.00	0.29	0.14	0.17	0.00	0.00	0.00	0.07	0.12	0.17	0.02	0.00	0.00	0.00	0.00	0.01
2486.33	0.50	Fox tail millet	0.13	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.56	0.00	0.29	0.00	0.00	0.01
10606.00	2.15	Tur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
1466.00	0.30	Bajra	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.03	0.00	0.85	0.00
17760.00	3.60	Onion	0.10	0.00	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00
8393.67	1.70	Horse gram	0.00	0.44	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.05	0.00	0.04
52818.33	10.71	Others	0.00	0.00	0.56	1.20	0.00	0.00	0.00	0.01	0.20	0.00	0.00	0.02	0.00	0.00	0.00	0.00

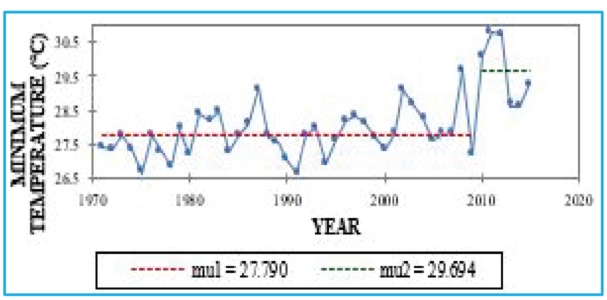

Fig. 21. Minimum temperature (°C) during July month

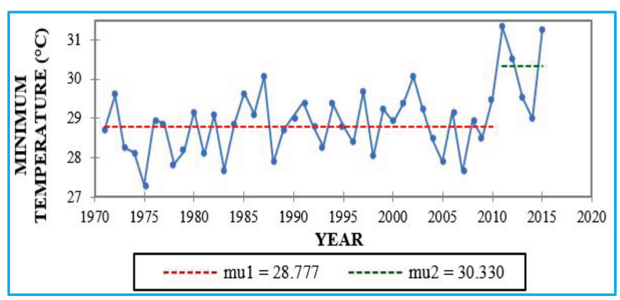

Fig. 23. Minimum temperature (°C) during September month

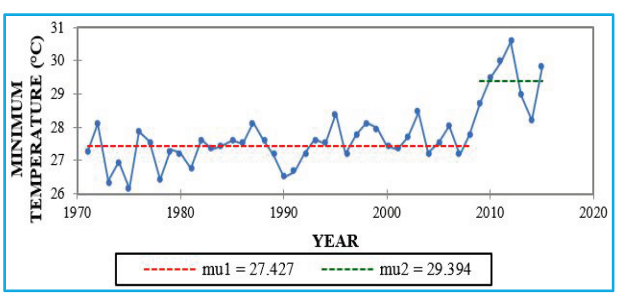

Fig. 22. Minimum temperature (°C) during August month

The increase in the minimum temperature (1.48 °C) was higher than the maximum temperature (0.59 °C) for August and September months in Chitradurga district. Various studies have made conclusions that increase in minimum temperature affects the growth and development of the crops significantly (Meehl *et al.*, 2007 and Bonsal *et al.*, 2001).

The results of homogeneity test conducted for minimum temperature of monsoon months are presented

TABLE 9

Estimates of autoregressive error correction model

Variable	DF	Estimate	Standard error	t Value	Approx Pr> |t|
Intercept	1	-2.6209	1.1536	-2.27	0.0382
ln Pre-monsoon	1	-0.0076	0.0107	-0.71	0.4865
ln South-west monsoon	1	0.0273	0.0153	1.78	0.0945
ln North-east monsoon	1	0.0099	0.0148	0.67	0.5129
ln Maximum temperature	1	0.5394	0.3173	1.70	0.1098
lLn Minimum temperature	1	0.2755	0.2575	1.07	0.3015
AR1	1	-0.2406	0.2905	-0.83	0.4204
AR2	1	-0.2458	0.3005	-0.82	0.4262

Note: R-Square 0.54, MSE 0.001

in Table 7. There was an increase in the minimum temperature during 2008, 2009, 2008 and 2010 in June, July, August and September months from 29.57 °C to 31.23 °C (Fig. 20), from 27.79 °C to 29.69 °C (Fig. 21), from 27.43 °C to 29.39 °C (Fig. 22) and from 28.78 °C to 30.33 °C (Fig. 23) respectively. Hence, the hypothesis that there is a gradual increase in temperature over the years could not be rejected. The increase in minimum temperature may affect the sowing, seed setting, evapotranspiration, crop water requirement and critical stages of crop growth resulting in negative effect to the crop production during the monsoon period (Meehl *et al.*, 2007 and Bonsal *et al.*, 2001).

3.2. *Transitional Probability Matrix (TPM) of cropping pattern*

The results of Markov chain analysis for the period 1998-2011 is presented in Table 8. Retention of area under cultivation is poor in almost all crops except sunflower (71%), maize (58%), foxtail millet (56%), areca nut (48%) and groundnut (43%) as reflected by the TPM. Sorghum gained its previous share in area from cotton (54%) and horse gram (44%) whereas it lost its previous share in area to groundnut (59%) and finger millet (35%). Groundnut gained its previous share in area from onion (76%), coconut (76%) and sorghum (59%) respectively. Sugarcane lost its previous share in area to finger millet(78%). Coconut lost its previous share in area to groundnut (76%). The area under rainfed crop, *viz*., maize has increased due to market forces towards commercialization of agriculture. Increased climate variability and rainfall aberrations during this decade the cultivation of water intensive crops such as areca nut and sugarcane decreased significantly and the area under the rainfed crops have increased significantly. Similar findings are reported by Meena *et al.* (2015) and Kondal *et al.* (2011). Based on the aforesaid results the hypothesis that, climate variability has influenced change in cropping pattern towards less water requirement crops could not be rejected (Sagar, 2016).

Impact of climate variability on agricultural production : The crop production is directly dependent on climate parameters and other minor variables. The relationship between the climatic parameters and the district agricultural GDP was studied by employing the AEC model and estimates are presented in Table 9. The results reveals that agricultural GDP of the Chitradurga district is significantly responsive to rainfall received during SW monsoon. For every one per cent increase in quantity of SW monsoon rainfall the agricultural GDP increases by 0.028 per cent. This signifies the growth and development of agriculture sector largely depends on climatic parameters. Any change or shift of climate parameters from the normal will have significant impact on the rural economy. These findings are corroborated by the results of the Nyuor *et al.* (2016); Ochieng *et al.* (2016), Singh *et al.* (2014) and Azuara *et al.* (2011). Hence, the hypothesis that climate variability has a negative impact on crop production and farmers' income could not be rejected.

4. Conclusions

Agriculture being continuously and directly affected by deviations in precipitation and temperature, the sector is considered as one among the most climate-sensitive sectors. It is found from the study that the annual rainfall received over the years did not show any shift or break in the long-term trend. Number of days with intensive rainfall (>7.5 mm) have increased in the study area. As intensive rains lead to soil erosion, loss of soil fertility through runoff and leaching; and overall soil degradation. Hence, suitable strategies such as better drainage need to be encouraged. Check bunds, infiltration tanks, water harvesting structures like farm ponds need to be incentivized and popularized among farmers to ensure the recharge of ground water in the backdrop of decreasing ground water table. Significant changes were observed in both daily maximum and minimum temperatures. Any changes in temperatures are reported to have an adverse effect on soil moisture, evapotranspiration and water demand. So, suitable measures for effective conservation and utilization of water such as bunding, mulching, drip irrigation and cultivation of drought tolerant varieties are to be promoted. Climate variability and climate change are inevitable and pose problem of losing agricultural income for the farmers particularly in the rainfed region. Therefore, the rainfed farmers should be encouraged to continue the agricultural operations by providing the agricultural inputs at the subsidized prices and necessary income support. Diversification strategies towards income, asset and livelihood play a crucial role in ensuring food security under climate change as they have the potential to address two of the Climate-Smart Agriculture (CSA) pillars by contributing to food security and adaptation to climate change. Providing incentives to adopt various diversification activities which help households to improve food security and become resilient to climate shocks need to be promoted. Climate variability will result in greater rainfall variability and uneven distribution. This promotes the cultivation of rainfed/drought tolerant crops instead of irrigated crops. Minor millets such as finger millet, foxtail millet, proso millet etc are considered to be drought tolerant and could be cultivated with least soil moisture. Hence, cultivation and consumption of the millets need to be incentivised and promoted in the backdrop of high climate variability.

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