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Original Article

Climate Change and Its Impact on Ragi Crop Productivity in Pune Division of Maharashtra

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Abstract

The research examines changing climatic condition and its correlation with the yield of Ragi crop. Climate change exerts a direct impact on the yield of Ragi crop. In Pune division, climatic parameters such as increase in average maximum temperature, fluctuation in rainfall intensity, decrease in relative humidity and increase in solar radiation highly affects crop yield. The present research work analyses climate change and its impact on the productivity of Ragi crop during the investigation period i.e. 1979 to 2013. Observations indicate that climate change affects Ragi crop productivity.

Keywords: *Climate Change, Ragi Crop, Correlation Analysis, Pune Division.*

Introduction

Climate and its elements are quite uncertain- not only regarding in Indian Monsoon but also in the World Climate- over the last five decades. The changing climatic condition always reflected through the fluctuating frequency and intensity of extreme weather condition and leads to putting pressure on global agriculture systems. Agricultural practices are basically associated with the anthropogenic adjunct concerning the local natural ecosystem. Agricultural production is directly related with the incidences of climatic condition and weather condition of spatial units. Possible changes in temperature, precipitation and CO_2 concentration are expected to bring significant effects on crop growth. The overall impact of climatic conditions on worldwide food production is considered to be low to moderate, assuming successful adaptation and adequate irrigation are utilized (IPCC, 1998). Agriculture is an economic activity highly dependent upon weather and climate to produce the food and fiber necessary to sustain human life (UNFCCC, 2011). However, agriculture is not only sensitive to climatic conditions but is also one of the major drivers of it. Understanding weather changes over a period of time and adjusting management practices towards achieving a better harvest are major challenges before the growth of the agricultural sector as a whole (FAO, 2009). The climate sensitivity of agriculture is uncertain, given that there is regional variation in rainfall, temperature, crops, cropping systems, soils, and management practices in the study area. Inter-annual variations in temperature and precipitation were found to be much higher than predicted changes. Consequently, crop losses would increase if the predicted increase in climatic conditions aligns with climate variability (IPCC, 2006). As climate is an important factor in agricultural productivity, the climatic data is correlated with the Ragi crop. In the present study an attempt has been made to establish an understanding of the relationship between climatic factors and productivity of Ragi crop in Pune division.

Study Area

Pune division is located in the South-Western part of Maharashtra state. It is extended between 15° 45′ N to 19° 0′ N latitude and 73° 32′ E to 76° 15′ E longitudes. The area under study covers five districts, namely Pune, Sangli, Satara, Solapur and Kolhapur having total 58 tehsils. The division is bounded by the Aurangabad district to the North and North-East, encircled by the Thane district to the North and North-West.

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The western boundary is delimited by Raigad and Ratnagiri districts whereas Sindhudurg district encloses the South and South-Western parts. Southern and Eastern boundaries are surrounded by Karnataka state and Eastern boundary is further delimited by the Osmanabad district. The region is divided into three parts: hilly, plateau and lowlands. Different ranges of Western Ghat are passes through the division. General slope decreases from western to eastern side. Temperature varies across different parts, with an average temperature of 25.62°C. The average annual rainfall in Pune division is 1239.09 mm. There are two major river basins i.e. Krishna and Bhima. The total geographical area of the region is about 57, 275 km². As per the 2011 census, the population was 2,34,49,051 with 58.76% located in rural areas and 42.24% in urban areas. The population density was 403 persons per km², and the sex ratio was 953 females per thousand males.

Objective

The main objective of the present research work is to analyse climate change and its impact on the productivity of Ragi crop in the Pune division.

Methodology

For the present research work, agricultural data set of 58 tehsils along with climatic data spanning 35 years (1979 to 2013) has been taken into consideration. Global weather data provided a data set of daily minimum and maximum temperatures, rainfall, solar radiation and relative humidity on a 0.25 x 0.25 grid scale.

Statistical methods used includes the mean, standard deviation, coefficient of correlation, and coefficient of variation. Regression analysis is applied using the following equations:

Simple Regression Equation:

$$Y = m + a X$$

Where,

- Y = Yield of crop (kg/ha)
- X = Weather parameter

Curvilinear Regression Analysis (Ezekiel and Fox, 1959):

$$Y = a + f_1 (X_1) + f_2 (X_2) + f_3 (X_3) + f_4 (X_4)$$

Where,

- Y = Yield of crop (kg/ha)
- X_1 = Rainfall (mm)
- X_2 = Temperature (°C)
- X_3 = Relative Humidity (%)
- X_4 = Solar radiation (MJ/M²)

The obtained data is converted into agro-climatic period-wise monthly averages and applied to the division. For proper study, the correlation analysis is done between climatic parameters and Ragi crops, 35 years are grouped into six categories, each containing five years as below:

- **Period A:** 1979-83 to 1984-88
- **Period B:** 1984-88 to 1989-93
- **Period C:** 1989-93 to 1994-98
- **Period D:** 1994-98 to 1999-03
- **Period E:** 1999-03 to 2004-08

These periods are used for normality test to denote climate change in comparison to other periods. The climatic parameters considered—maximum temperature, minimum temperature, rainfall, relative humidity, and solar radiation—are correlated with the Ragi crop. Tabulation is carried out through MS-Excel and Windows Office 2010.

Climate Change and Its Correlation with the Productivity of Ragi Crop

The scientific name of Ragi is *Eleusine Coracana*. Ragi crop is also known as finger millet. In India, it is locally called Ragi or Nachani. It is a kharif crop particularly cultivated from June to October in the study area, though it is not strictly a season-bound crop and can be cultivated year-round depending on moisture availability. It typically grows in temperatures between 18°C and 27°C, areas with more than 1500 mm rainfall and altitudes of 500 to 1400 m above Mean Sea Level (MSL), particularly in Western Ghats areas with laterite and red soil. It is grown as a rain-fed crop in moist climatic conditions prevailing in the western portions of Pune, Satara, Sangli and Kolhapur districts.

Climatic Condition and Production of Ragi Crop

The Ragi crop is completely dependent on monsoonal climatic condition in the Pune division. The cultivated area receives an average rainfall of 2000 mm which is ample for this crop.

Table 1

Variability in Climatic Parameters in the Ragi Producing Areas of Pune Division (1979-2013)

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Months	Parameter Type	Rainfall (mm)	Max Temp. (°C)	Min Temp. (°C)	Mean Temp. (°C)	Relative Humidity (%)	Solar Rad (MJ/M²)
June	Mean	481.81	27.56	21.93	24.75	84.94	14.26
	S.D.	122.90	1.88	0.34	1.06	4.73	2.60
	C.V.	25.51	6.84	1.56	4.29	5.57	18.20
July	Mean	598.12	23.67	21.22	22.45	94.94	8.05
	S.D.	144.66	0.60	0.32	0.39	1.35	1.93
	C.V.	24.19	2.52	1.49	1.74	1.42	23.94
August	Mean	507.37	23.54	20.72	22.13	95.69	8.11
	S.D.	96.42	0.94	0.35	0.53	1.16	1.94
	C.V.	19.00	3.98	1.68	2.40	1.21	23.90
September	Mean	349.58	26.18	19.73	22.96	91.43	15.20
	S.D.	128.64	1.12	0.66	0.54	2.77	2.59
	C.V.	36.80	4.28	3.33	2.35	3.03	17.04
October	Mean	169.07	29.31	18.58	23.92	75.51	18.19
	S.D.	97.04	1.45	0.73	0.79	7.00	1.31
	C.V.	57.40	4.94	3.91	3.30	9.27	7.21
Season Average	Mean	421.19	26.05	20.44	23.24	88.50	12.76
	S.D.	117.93	1.20	0.48	0.66	3.40	2.07
	C.V.	32.58	4.51	2.39	2.82	4.10	18.06

Source: The Global Weather Data (1979 to 2013).

Rainfall varies significantly, with the standard deviation peaking in July (598.12 ± 144.66 mm), followed by August, June, September, and October. The coefficient of variation for rainfall ranges from 19.00% to 57.40%. Pune division has 23.25°C as an average temperature. The region has experienced average minimum and maximum temperature 20.43°C and 26.13°C, respectively. Relative humidity averages 88.60%, peaking in August (95.69 ± 1.16%). Solar radiation averages 12.76 MJ/M², though cloudy conditions in July and August drop this to below 9 MJ/M².

Regression Analysis

Regression analysis indicates that there is a high perfect positive relationship between the productivity of Ragi and climatic variables (R-value = 0.981). The R^2 value is 0.962 (96% variation explained), and the Adjusted R^2 is 0.950.

Table 2

Regression Statistics of Ragi Crop (1979-2013)

Regression Statistics	Value
Multiple R	0.981
R Square	0.962
Adjusted R Square	0.950
Standard Error	0.097
Observations	35

Sources: The Global Weather Data & Govt. of Maharashtra, Socio-Economic Abstract (1979 to 2013).

The significance P-value of 0.000 (<0.05) strongly proves a direct relationship between climatic parameters and the productivity of Ragi. The regression equation reveals that minimum temperature, maximum temperature, rainfall and relative humidity have negative impact. However, mean temperature and solar radiation have positive impacts on the productivity of Ragi crop.

Matrix Correlation Analysis

The correlation matrix reveals,

- **Rainfall vs. Yield:** High perfect positive correlation (0.859), indicating it is highly momentous.
- **Temperature vs. Yield:** High positive correlation (0.832).
- **Relative Humidity vs. Yield:** Moderate positive correlation (0.436).
- **Solar Radiation vs. Yield:** Moderate level correlation.

Impact of Climatic Condition on Ragi Yield

An assessment of specific element changes against Ragi yield over the 35 years is presented below:

Table 3

Climatic Condition and its Relationship with Ragi Yield in Pune Division (1979-2013)

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5 Years Period	Yield (Kg/ha)	Rain (mm)	Temperature (°C)			Relative Humidity (%)	Solar Radiation (MJ/M²)
			Maximum	Minimum	Mean		
A	-110.12	-351.51	-0.58	-0.17	-0.35	-0.14	0.66
B	45.36	419.25	0.35	-0.16	0.10	1.26	-1.17
C	100.78	153.25	0.24	0.26	0.25	0.56	-0.89
D	-190.76	-655.86	-0.09	0.54	0.23	-2.28	1.13
E	51.12	219.70	0.04	-0.09	-0.03	-0.04	-1.01
F	113.18	308.42	-0.09	-0.15	-0.12	2.56	-0.47
Correlation (R^2)		**0.94**	**0.56**	**-0.49**	**0.07**	**0.85**	**-0.67**

It is observed that the yield of Ragi is highly correlated with the amount of rainfall (R^2 = 0.94). A significant decrease in amount of rainfall i.e. -655.86 mm during Period D has noticed to a corresponding decrease of 190.76 kg/ha in the yield of Ragi crop. Period F has experienced rise in rainfall by 300 mm and as a result, the yield of Ragi is also increased up to 113.10 kg/ha.

Ragi crop requires 20°C to 40°C temperature, with optimum 32°C during daytime and 25°C through nights. If, 1°C increase in temperature is combined with a 5% decrease in radiation, yield of Ragi also decreases by 9% (Hundal and Kaur, 2007). It is found that, Period D underwent high temperature deviation (0.54°C) in minimum temperature than the average and then there is significant decrease in the yield of Ragi up to 190.76 kg/ha in the study region.Relative humidity in the atmosphere is also an important variable affecting on the yield of Ragi crop. During the total period of investigation, it is observed that there is a high positive correlation i.e. 0.85/0.88 between relative humidity and the yield of Ragi crop. A decrease in the proportion of humidity by -2.28% in Period D has significantly decreased yield of Ragi crop. It is found that, an increase of 2.56% humidity during Period F has also raised yield of Ragi crop up to 113.18 kg/ha. Ragi crop always influenced by climatic variables in its ripening period of last 35 to 45 days. However, during the period of investigation, it is observed that there is a negative correlation (-0.67) between the yield of Ragi crop and the amount of solar radiation; even though there is slight increase in solar radiation by 1.13 MJ/M² in Period D has decreased the yield of Ragi crop and during Period B there is a decrease of -1.17 MJ/M² and increased yield of Ragi crop

Conclusion

Ragi is an important staple food requiring high temperature. There is a high positive correlation between the Ragi crop and temperature (0.832) and rainfall (0.859) in Pune division. There is moderate correlation with relative humidity (0.435) and solar radiation (0.435) during the period of investigation. The regression with crop yield is calculated as 0.962. During Period D (1994-98 to 1999-03), an average maximum temperature increase of 0.54°C paired with a rainfall decrease of over 500 mm led to a production decrease of 200 kg/ha. During the same period, relative humidity decreased by 2% and solar radiation increased by more than 1 MJ/M²; simultaneously both these parameters have affected the yield of Ragi and it is decreased.

During Periods C (1989-93 to 1994-98) and F (2004-08 to 2009-13), rainfall increased by more than 100 mm, maximum temperatures decreased by 0.50°C to 1.00°C, relative humidity increased by 2.00%, and these factors increased yield by more than 100 kg/ha. These values clearly indicate a perfect positive correlation with climatic elements. It is concluded that the amount of rainfall, temperature, relative humidity and solar radiation significantly effects on the yield of Ragi crop.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper

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