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Analysis of precipitation concentration index and impact of climate change on productivity of selected crops in Akola district of Maharashtra

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Abstract
Agriculture sector is more vulnerable to changing climate compared to other sectors. Looking to the adverse climatic situation and persistent changes in area, production and productivity of major crops in study area, it is felt necessary to analyze the variability of rainfall and impact of climatic factors on productivity of selected crops in Akola district. So, the present study has been conducted to analyse the Precipitation Concentration Index and impact of climate change on productivity of selected crops in Akola district of Maharashtra. Time series data ranging from 2000-01 to 2020-21 on productivity of cotton, gram, tur, wheat and soybean crop has been taken from government publications, websites. The data of selected climatic factors such as rainfall, maximum temperature, minimum temperature, morning relative humidity, evening relative humidity has been collected from Department of Agronomy, Dr. PDKV, Akola. The variability of rainfall of study period for Akola district has been analyzed by using precipitation concentration index. The effect of climate change on the productivity of cotton, gram, tur, wheat, and soybean has been studied using the multiple linear regression technique. For Akola district, there is overall irregular distribution of rainfall over period from 2000-01 to 2020-21. It is observed that, for kharif season the distribution of rainfall over a period ranging mainly from uniformly distributed to moderately distributed for Akola district. Also the rainfall distribution ranging from moderately distributed to strongly irregular distribution in Akola district during rabbi season. Similarly, summer season also showing same range of rainfall i.e. from moderately distributed to strongly irregular distribution for Akola district. According to the results of the multiple regression equation, climatic conditions are responsible for 59 per cent of the variation in cotton productivity. Soybean productivity varies by 38 per cent, and this fluctuation is caused by climatic factors. According to the findings, 74 per cent of the variation in gram productivity is observed due to climatic factors. The climatic factor are responsible for 59 per cent of the fluctuation in tur productivity and also about 17 per cent of the variation in wheat productivity is observed.

Keywords: Climate change, precipitation concentration index, productivity, multiple linear regression

1. Introduction

The biggest environmental concern of the twenty-first century is climate change. All spheres of life, including agriculture, have undergone change. Particularly, the impact of climate change on Indian agriculture is minimal. Climate change, according to (Anonymous, 2007) [1], is simply a statistically significant variation in either the mean state of the climate or in its variability that has persisted for a longer time. This variance may be the result of changes in natural or artificial external forcing, as well as internal natural processes that took place inside the climate system. At various stabilized levels of CO_2 in the atmosphere, the pace of warming temperature in the twenty-first century will range between 0.8 °C and 4.4 °C, reaching 3 °C by the end of the century. The main causes of this significant climate change are human activity and increased atmospheric carbon dioxide emissions. So, according to (Anonymous, 2021) [2] the years 2016 and 2020 are deemed the warmest years ever. Beyond just crops, climate change has an impact on how food is produced. It will have an impact on agricultural production systems, which will either directly or indirectly affect food production and food security. On a local, regional, national, and international level as well as in terms of agricultural productivity, the effects of climate change are significant. This study intends to determine how climatic factors affect the productivity of particular crops in the Akola district.

2. Methodology

The nature of the present study is mainly based on secondary data. The study's goals have been attained by analysing pertinent secondary data for a period of 21 years, from 2000-01 to 2020-21.

2.1. Collection of Data

For productivity of selected crops the study was based on secondary data mainly collected from various government reports, publications and related websites. While for climatic data, it was collected from Department of Agronomy, Dr. PDKV, Akola. Total five major crops were taken. i.e. Tur, Wheat, Soybean, Gram and Cotton for Akola district of Maharashtra state with 21 years data from 2000-01 to 2020-21 was utilized for this study.

2.2. Analytical tools

2.2.1. Precipitation Concentration Index

This method is proposed by Oliver (1980) [8]. PCI is used to understand the rainfall variability.

$$PCI_{annual} = \frac{\sum_{i=1}^{12} P_i^2}{(\sum_{i=1}^{12} P_i)^2} \times 100$$

$$PCI_{seasonal} = \frac{\sum_{i=1}^{4} P_i^2}{(\sum_{i=1}^{4} P_i)^2} \times 33.33$$

Where,
PCI = Precipitation Concentration index
P_i = Precipitation in month 'i'

Table 1: Criteria for classification of years on the basis of Precipitation Concentration index (PCI)

PCI	Rainfall regime
<10	Uniform precipitation concentration
11-15	Moderate precipitation concentration
16-20	Irregular precipitation concentration
>20	Strongly irregular precipitation concentration

2.2.2. Multiple Linear Regression

By using multiple linear regression, the impact of climate change on productivity of selected crops were analyzed.

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$$

Where,
Y = Productivity kg/ha
a = Intercept
X_1 = Rainfall (mm)
X_2 = Maximum Temperature (°C)
X_3 = Minimum Temperature (°C)
X_4 = Morning Relative Humidity (%)
X_5 = Evening Relative Humidity (%)

3. Results and Discussion

3.1. Precipitation Concentration Index

The variability of rainfall of study period for Akola district were analyzed by using precipitation concentration index.

Table 2: Year wise Annual and Seasonal PCI

Years	Annual PCI	Seasonal PCI		
		Kharif	Rabbi	Summer
2000-01	20.98	10.21	33.33	17.22
2001-02	17.02	9.77	21.95	16.11
2002-03	26.43	10.29	29.49	14.57
2003-04	24.76	8.65	21.37	33.33
2004-05	17.43	8.99	14.48	21.61
2005-06	22.09	10.53	19.83	24.21
2006-07	19.48	9.79	30.14	16.79
2007-08	25.24	9.08	33.33	31.85
2008-09	22.57	9.21	13.24	33.33
2009-10	18.57	11.13	14.93	30.06
2010-11	22.19	9.47	11.27	21.86
2011-12	22.25	9.05	33.33	13.68
2012-13	24.92	9.76	25.91	29.29
2013-14	20.82	8.79	21.11	15.74
2014-15	28.48	12.57	24.89	11.21
2015-16	23.59	11.42	33.33	15.13
2016-17	26.98	11.37	33.33	33.33
2017-18	24.57	9.99	33.33	17.71
2018-19	28.78	9.81	33.33	17.19
2019-20	22.29	9.52	20.48	26.12
2020-21	23.87	9.35	24.34	17.89

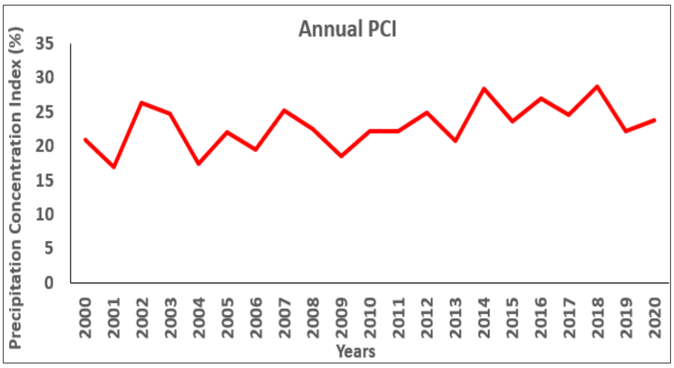

Fig 1: Showing the annual precipitation concentration index (%) for Akola district from the period of 2000-01 to 2020-21. From figure it is observed that, PCI is more in the 2018-19 which indicates that there is very strong irregular distribution of rainfall during respective year. Likewise remaining years also showing that there is irregular distribution of rainfall in Akola district.

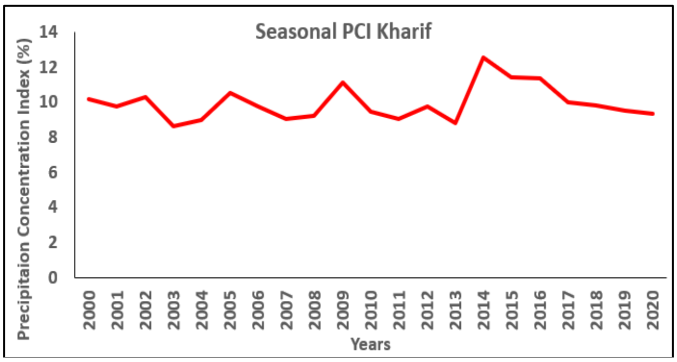

Fig 2: Showing the seasonal precipitation concentration index (%) mainly for kharif season in Akola district from the period of 2000-01 to 2020-21. It is observed that, the years like 2000-01, 2002-03, 2005-06, 2009-10, 2014-15, 2015-16 and 2016-17 showing moderate distribution of rainfall during kharif season in Akola district. Remaining years showing PCI values less than 10 implies that there is uniform distribution of rainfall during these years in kharif season.

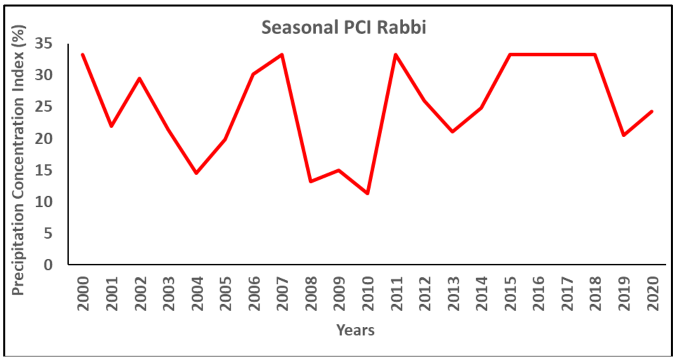

Fig 3: Showing the seasonal precipitation concentration index (%) mainly for rabbi season in Akola district from the period of 2000-01 to 2020-21. It is observed that, during the years of 2004-05, 2008-09, 2009-10 and 2010-11 the PCI values are less than 16 which indicating that there is moderate distribution of rainfall during these years in Akola district. While remaining years representing the strongly irregular distribution of rainfall in Akola district during rabbi season.

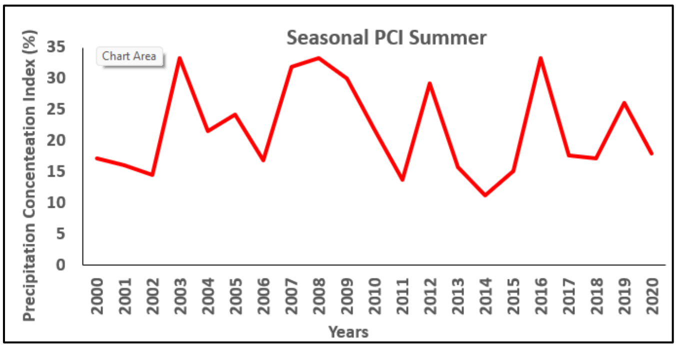

Fig 4: Showing the seasonal precipitation concentration index (%) mainly for summer season in Akola district from the period of 2000-01 to 2020-21. During summer season, it is observed that 2003-04, 2008-09 and 2016-17 years having highest PCI value which indicates that there is strong irregular distribution of rainfall in Akola district during these years. Also, years like 2011-12, 2013-14, 2014-15 and 2015-16 showing PCI values less than 16 implies that there is moderate distribution of rainfall during these years.

3.2. Multiple Linear Regression

Impact of different climatic factors such as rainfall, maximum temperature, minimum temperature, morning relative humidity, evening relative humidity on productivity of selected crop was analysed by using Multiple Regression Technique.

Table 3: Impact of climate change on productivity of tur

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	F	p value
1	0.77	**0.59**	0.45	398.47	4.22	0.01

The obtained multiple regression equation had an R^2 value of 0.59, which indicates that climatic variables like rainfall, maximum temperature, minimum temperature, morning relative humidity, and evening relative humidity during the crop duration period account for about 59% of variation in tur productivity. As can be seen from the above table, the estimated multiple regression model is significant because the p value is less than the level of significance, which in this case is 0.05, and the F value is more than 1.

Table 4: Multiple linear regression model for tur

Model	B	Std. Error	t value	p value
Constant	1196.72	10396.25	0.12	0.91
Rainfall (mm)	2.76	5.08	0.54	0.59
Maximum Temperature (℃)	50.95	249.99	0.20	0.84
Minimum Temperature (℃)	-421.02	190.73	-2.21	0.04
Morning Relative Humidity (%)	55.07	36.57	1.51	0.15
Evening Relative Humidity (%)	37.61	43.73	0.86	0.40

The resultant multiple regression equation is derived and expressed as,

$$Y = 1196.72 + 2.76X_1 + 50.95X_2 - 421.02X_3 + 55.07X_4 + 37.61X_5$$

Where Y is productivity of tur, X_1 is rainfall (mm), X_2 is maximum temperature (℃), X_3 is minimum temperature (℃), X_4 is morning relative humidity (%), X_5 is evening relative humidity (%). From this equation, it is observed that minimum temperature shows negatively significant relationship while rainfall, maximum temperature, morning relative humidity, evening relative humidity found positive but non-significant effect on productivity of tur.

Table 5: Impact of climate change on productivity of wheat

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	F	p value
1	0.41	**0.17**	-0.11	463.74	0.61	0.69

According to the obtained multiple regression equation, which had an R^2 value of 0.17, climatic variables like rainfall, maximum temperature, minimum temperature, morning relative humidity, and evening relative humidity during the crop's growing season account for about 17 per cent of the variation in wheat productivity. The estimated multiple regression model is non-significant since the p value of the model is more than the level of significance, which is 0.05, and the F value of the model is less than one, as shown in the above table.

Table 6: Multiple linear regression model for wheat

Model	B	Std. Error	t value	p value
Constant	1753.42	7405.33	0.24	0.82
Rainfall (mm)	5.86	8.91	0.66	0.52
Maximum Temperature (℃)	-66.52	197.79	-0.34	0.74
Minimum Temperature (℃)	85.98	123.02	0.69	0.49
Morning Relative Humidity (%)	23.61	26.03	0.91	0.38
Evening Relative Humidity (%)	-31.57	32.87	-0.96	0.35

The resultant multiple regression equation is derived and expressed as,

$$Y = 1753.42 + 5.86X_1 - 66.52X_2 + 85.98X_3 + 23.61X_4 - 31.57X_5$$

Where Y is productivity of wheat, X_1 is rainfall (mm), X_2 is maximum temperature (℃), X_3 is minimum temperature (℃), X_4 is morning relative humidity (%), X_5 is evening rela tive humidity (%). From this equation, it is observed that maximum temperature and evening relative humidity shows negatively but non-significant relationship while rainfall, minimum temperature, morning relative humidity, found positive but non-significant effect on productivity of wheat.

Table 7: Impact of climate change on productivity of soybean

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	F	p value
1	0.61	**0.38**	0.17	467.32	1.81	0.17

The obtained multiple regression equation had an R^2 value of 0.38, indicating that climatic variables like rainfall, maximum temperature, minimum temperature, morning relative humidity, and evening relative humidity at the crop duration period account for about 38% of the variation in soybean productivity. The estimated multiple regression model is non-significant because, as shown in the above table, the p value of the model is greater than the level of significance, which is 0.05.

Table 8: Multiple linear regression model for soybean

Model	B	Std. Error	t value	p value
Constant	16630.93	13996.31	1.19	0.25
Rainfall (mm)	7.76	3.51	2.21	0.04
Maximum Temperature (℃)	-417.11	295.14	-1.41	0.18
Minimum Temperature (℃)	141.95	219.69	0.65	0.53
Morning Relative Humidity (%)	-55.22	83.74	-0.66	0.52
Evening Relative Humidity (%)	-31.07	88.24	-0.35	0.73

The resultant multiple regression equation is derived and expressed as,

$$Y = 16630.93 + 7.76X_1 - 417.11X_2 + 141.95X_3 - 55.22X_4 - 31.07X_5$$

Where Y is productivity of soybean, X_1 is rainfall (mm), X_2 is maximum temperature (℃), X_3 is minimum temperature (℃), X_4 is morning relative humidity (%), X_5 is evening relative humidity (%). From this equation, it is observed that rainfall positively significant relationship while minimum temperature shows positive but non significant relationship with productivity. Also maximum temperature, morning relative humidity and evening relative humidity found negative but non-significant effect on productivity of soybean.

Table 9: Impact of climate change on productivity of gram

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	F	p value
1	0.86	**0.74**	0.65	206.45	8.31	0.00

The multiple regression equation obtained showed R^2 value equal to 0.74, this implies that about 74 per cent of variation in productivity of gram is accounted by the climatic factors such as rainfall, maximum temperature, minimum temperature, morning relative humidity, evening relative humidity at crop duration period. From above table, it is revealed that p value of model is less than the level of significance i.e. 0.05 which indicates that the estimated multiple regression model is significant.

Table 10: Multiple linear regression model for gram

Model	B	Std. Error	t values	p values
Constant	-3516.73	3940.82	-0.89	0.39
Rainfall (mm)	3.39	3.79	0.89	0.39
Maximum Temperature (℃)	40.29	105.42	0.38	0.71
Minimum Temperature (℃)	-28.65	57.66	-0.49	0.63
Morning Relative Humidity (%)	44.81	12.29	3.65	0.00
Evening Relative Humidity (%)	2.85	12.16	0.23	0.82

The resultant multiple regression equation is derived and expressed as,

$$Y = -3516.73 + 3.39X_1 + 40.29X_2 - 28.65X_3 + 44.81X_4 + 2.85X_5$$

Where Y is productivity of gram, X_1 is rainfall (mm), X_2 is maximum temperature (℃), X_3 is minimum temperature (℃), X_4 is morning relative humidity (%), X_5 is evening relative humidity (%). From this equation, it is observed that morning relative humidity shows positively significant relationship while rainfall, maximum temperature and evening relative humidity shows positive but non significant relationship with productivity. Also minimum temperature found negative but non-significant effect on productivity of gram.

Table 11: Impact of climate change on productivity of cotton

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	F	p value
1	0.77	**0.59**	0.45	95.17	4.31	0.01

The obtained multiple regression equation had an R^2 value of 0.59, indicating that climatic variables like rainfall, maximum temperature, minimum temperature, morning relative humidity, and evening relative humidity during the crop's growing season account for about 59% of variation in cotton productivity. The calculated multiple regression model is significant, as shown by the above table, where the p value of the model is less than the level of significance (0.05).

Table 12: Multiple linear regression model for cotton

Model	B	Std. Error	t values	p values
Constant	-774.24	2298.35	-0.34	0.74
Rainfall (mm)	2.27	1.07	2.13	0.05
Maximum Temperature (℃)	4.53	55.62	0.08	0.94
Minimum Temperature (℃)	-21.89	41.05	-0.53	0.60
Morning Relative Humidity (%)	13.67	9.43	1.45	0.17
Evening Relative Humidity (%)	0.34	11.08	0.03	0.98

The resultant multiple regression equation is derived and expressed as,

$$Y = -774.24 + 2.27X_1 + 4.53X_2 - 21.89X_3 + 13.67X_4 + 0.34X_5$$

Where Y is productivity of gram, X_1 is rainfall (mm), X_2 is maximum temperature (℃), X_3 is minimum temperature (℃), X_4 is morning relative humidity (%), X_5 is evening relative humidity (%). From this equation, it is observed that rainfall shows positively significant relationship while maximum temperature, morning relative humidity and evening relative humidity shows positive but non significant relationship with productivity. Also minimum temperature found negative but non-significant effect on productivity of cotton.

4. Conclusion

This study presents the analysis of Precipitation Concentration Index and impact of climate change on productivity of selected crops in Akola district of Maharashtra by using annual data covering the period from 2000-01 to 2020-21. The results obtained from the present study are summarized in the following conclusion. For Akola district, there is overall irregular distribution of rainfall over period from 2000-01 to 2020-21. It is observed that, for kharif season the distribution of rainfall over a period ranging mainly from uniformly distributed to moderately distributed for Akola district. Also the rainfall distribution ranging from moderately distributed to strongly irregular distribution in Akola district during rabbi season. Similarly, summer season also showing same range of rainfall i.e. from moderately distributed to strongly irregular distribution for Akola district. According to the results of the multiple regression equation, climatic conditions are responsible for 59 per cent of the variation in cotton productivity. Soybean productivity varies by 38 per cent, and this fluctuation is caused by climatic factors. According to the findings, 74 per cent of the variation in gram productivity is observed due to climatic factors. The climatic factor are responsible for 59 per cent of the fluctuation in tur productivity and also about 17 per cent of the variation in wheat productivity is observed.

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