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IMPACT OF CLIMATIC FACTORS ON PRODUCTIVITY OF MAIZE

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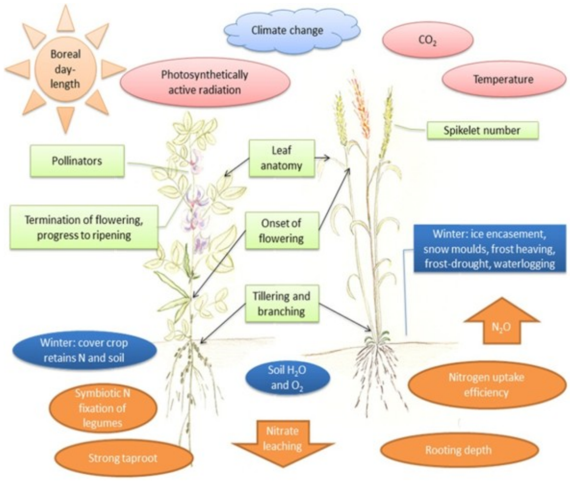
Abstract

Climate is one of the main determinants of agricultural production since climatic factors serve as direct inputs to agriculture. Any change in climatic factors is bound to have a significant impact on crop yields and production. The present study, gives information about an impact of different weather parameters on the yield of maize. Secondary data of weather parameters for 30 years (1984-2013) was obtained from Zonal Agricultural Research Station, Kathalagere. The weather parameters viz., minimum temperature (°C), maximum temperature (°C), relative humidity (per cent), rainfall (mm), sunshine hours (hrs/day) and evaporation (mm) were considered for this study. Correlation and regression analysis were carried out to know the impact of climatic factors on yield of maize crop. The maize yield had positive correlation with all the weather parameters except evaporation and sun shine hours. Further, it revealed that rainfall had highly significant positive relation with maize crop yield except evaporation and sun shine hours. Also, the crop yield was found to be positively influenced by rainfall and negatively by evaporation with R^2 value of 0.77. The errors due to the fitted model were found to be random and approximately normally distributed and this was verified by using runs test and normal probability plot respectively.



Key words: Weather parameters, Maize yield, Correlation and Regression analysis.

INTRODUCTION

Climate is a measure of average pattern of variation in temperature, humidity, atmospheric pressure, wind speed, precipitation, atmospheric particle count and other meteorological variables in a given region over long periods of time. A region's climate is generated by the climate system, which has five components viz., atmosphere, hydrosphere, cryosphere, lithosphere and biosphere.

Climatic variability is the major factor influencing agriculture productivity. In particular, since agriculture production is highly dependent on climate, it is also adversely affected by increasing climatic variability. Climate change is one of the most important global environmental challenges facing humanity with implications for food production, natural ecosystems, freshwater supply, health, etc. In general, its impacts on agriculture have become an important issue.

Maize *(zea mays)* is an important staple food in many countries of the world and the acreage and production of maize in the world have been increasing continuously. Use of maize for biofuel production increases the demand, and therefore price of maize. This, in turn, results in farm acreage being diverted from other food crops to maize production. This reduces the supply of the other food crops and increases their prices. Though the acreages have not been so erratic, the production has been a bit volatile mainly due to the variations in the yield. The area under maize is continuously increasing over the years. Maize is largely grown in north India. Highest concentration of the crop is found in Uttar Pradesh, Rajasthan, Madhya Pradesh, Bihar, Himachal Pradesh, Jammu and Kashmir and Punjab which together account for two-third of the total area and output of the crop.

Maize is widely cultivated throughout the world, and a greater weight of maize is produced each year than any other grain. The United States produces 40% of the world's harvest; other top producing countries include China, Brazil, Mexico, Indonesia, India (6^{th} position), France and Argentina. Worldwide production was 817 million tonnes in 2009 more than rice (678 million tonnes) or wheat (682 million tonnes). In 2009, over 159 million hectares (390 million acres) of maize were planted worldwide, with a yield of over 5 tonnes per hectare. There is conflicting evidence to support the hypothesis that maize yield potential has increased over the past few decades. This suggests that changes in yield potential are associated with leaf angle, lodging resistance, tolerance of high plant density, disease/pest tolerance, and other agronomic traits rather than increase of yield potential per individual plant.

Climate change has significant impact in terms of variations in weather parameters. For instance, in recent years, July rains are decreasing and August rains are increasing and hence the sowing is extending up to mid-August. Due to this delayed sowing, tassel, silk initiation percentage reduces and total yield reduces. The maize crop suffered substantial damage because of high as well as low rainfall at different stages of crop growth. Due to climate change, mid-season droughts are increasing due to dry weather, suffering of plants from lack of water, depletion of underground water supply. The crop can be grown successfully in places where it receives a minimum rainfall of 550 mm and a maximum of 1200 mm. However, the crop cannot stand frost, long and severe drought or water stagnation.

The climatic factors play an important role in agricultural productivity and sustainability of water bodies around a region. The study on an impact of climatic factors on crop yield will reflect on the planning of agricultural operations. There are many studies relating to an impact of climatic factors on crop yield. Prominent among them being Santhosh(2011), Govinda (2013) and Elbariki*et al*., (2014).

The maize crop is grown extensively in Davanagere taluk by farmers by cultivating the crop under dry land agriculture under varied climatic conditions. But however, not much research works on this was carried out in this region. Considering the above mentioned facts, the present study was conducted to analyze the impact of climatic factors on productivity of maize at kathalagere station in Central Karnataka.

MATERIAL AND METHODS

Description of study area

The present study was conducted to know the impact of climatic factors on productivity of maize at Kathalagere station which belongs to the Southern Transition (Zone-VII) situated at Davanagere district in Central Karnataka with normally moderate climate and medium rain fall. The station is located at 14°17' N latitude, 75°50' longitude and 602.5 meters above sea level. Davanagere district receives average annual rainfall of 644 mm. The months of March and April are the hottest months of the year.

Weather parameters:

The secondary data on weather parameters and yield of maize over a period of 30 years (1984-2013) was collected from ZARS, Kathalagere. The parameters considered are:

X_1: Maximum temperature (^oC), X_2: Minimum temperature (^oC), X_3: Relative humidity (%), X_4: Rainfall (mm), X_5: Evaporation (mm) and X_6: Sunshine (hrs).

Analytical tools and techniques applied

To assess the impact of climatic factors on crop yield, the tool such as correlation, simple and multiple regression analysis were carried out.

Karl-Pearson's coefficient of correlation (r_{xy}):

$$\boldsymbol{\rho_{xy} = \mathrm{corr}(x, y) = \frac{\mathrm{cov}(x, y)}{\sigma_x \sigma_y} = \frac{E[(X - \mu_X)(Y - \mu_Y)]}{\sigma_x \sigma_y}}$$

$\mathrm{cov}(x, y)$= Covariance between weather variable (X) and Yield (Y),

σ_X = Standard deviation of weather variable (X),

σ_Y = Standard deviation of Yield variable (Y).

Simple Linear Regression Analysis

The simple linear regression models were fitted using crop yield as dependent variable (Y) and each weather parameter as independent variables (X_1, X_2,…,X_6) one at a time.

$Y_{ij} = \beta_o + \beta_1 X_{ij} + e_{ij}$ where, i = 1,2,…,6 and j = 1,2,.....,30

Multiple Linear Regression Analysis

The multiple linear regression models relating the crop yield (Y) to the weather parameters (X_i) can be expressed as,

$$Y = X\beta + \varepsilon$$

Where, $Y' = (Y_1, Y_2, ..., Y_n)$ is the vector of values of the dependent variable (yield of maize).

$$X = \begin{bmatrix} 1 & X_{11} & \ldots & X_{1k} \\ 1 & X_{21} & \ldots & X_{2k} \\ . & . & \ldots & . \\ . & . & \ldots & . \\ . & . & \ldots & . \\ 1 & X_{n1} & \ldots & X_{nk} \end{bmatrix}$$, a (n x p) matrix

$\beta' = (\beta_1, \beta_2, ..., \beta_k)$is the vector of the parameters and $\varepsilon' = (\varepsilon_1, \varepsilon_2, ..., \varepsilon_k)$ is the error vector. The error vector ε was assumed to be normally distributed with N $[0, \sigma^2]$. The least square estimator of the parameter vector β is

$$\hat{\beta} = b = (X'X)^{-1} X'Y$$

Model Adequacy Checking

Adequacy of a model depends on the validity of assumptions underlying the model. The assumptions made in a linear regression model are, apart from linear-dependence of Y on predictors, independence and identical distribution (normal) of the predictors with zero mean. Gross violations of the assumptions may lead to an unstable model in the sense that a different sample could lead to a totally different model with opposite conclusions. We cannot detect departures from the underlying assumption by examination of the summary statistics such as t or F statistic or R^2 (Draper and Smith, 1981). These are Global model properties and as such they do not ensure model adequacy. Hence, diagnostic methods, primarily based on the study of the model residuals are used. The diagnostics checks that were used for the present study include randomness and normality of residuals.

Coefficient of Determination (R^2)

The statistic R^2, the coefficient of determination indicates the percentage of variation in the dependent variable explained by the independent variables included in the regression model. The R^2 is computed using the uncorrected sum of squares as

$$R^2 = \frac{\sum_{i=1}^{n} (\hat{y}_i - \bar{y})^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2}$$ Where, $0 \leq R^2 \leq 1$

Assumptions of error term

An important assumption of multiple regression models is that the residual, ε follows normal distribution. This assumption is required to test the hypothesis about the regression coefficients. This assumption can be verified using,

(i) Test for randomness of error terms

(ii) Normal probability plots.

Randomness of error terms (Runs test)

Randomness of residuals is tested using the non-parametric one sample runs test.

A run is defined as the succession of identical symbols which are followed and preceded by different symbols or no symbols at all. The null and alternative hypothesis is given by

H_0: The sequence of residuals is random vs H_1: The sequence of residuals is not random.
Let n_1 be the number of elements of one kind and n_2 be the number of elements of the other kind in a sequence of $N = n_1 + n_2$ binary events. If both n_1 and n_2 are less than or equal to 20, and if the number of runs (r) falls between the critical values provided in the tables, we cannot reject the null hypothesis.

Normal probability plot

Suppose $e_1, e_2, \ldots, e_n$ are the residuals ranked in increasing order as $e_1 < e_2 < \ldots < e_n$. If we plot e_i against the cumulative probabilities $P_i = (i-1/2)/n$, $i=1,2,\ldots,n$, we get the normal probability plot. The residuals can be assumed to be normally distributed if the resulting points lie approximately on a straight line.

RESULTS AND DISCUSSION

In order to test the specified objective of the present investigation, the data on the weather parameters and the yield of maize crop was subjected to statistical analysis. The results of the analysis are presented under the following headings:

Karl-Pearson's correlation coefficient (r_{xy}):

The correlation coefficients between weather parameters and maize yield were calculated on the basis of 30 years data. The results are presented in Table 1. From the table, it was noticed that the maize yield had positive correlation with all the weather parameters except evaporation and sun shine hours (Similar results were observed by Sathosh (2011) and Elbariki *et al*., (2014). The correlation results also revealed that rainfall had significantly influenced by maize crop yield positively except evaporation and sun shine hours.

Table 1.Correlation between maize yield (kg/ha) and weather parameters

	Max.Temp	Min.Temp	RH	RF	ET	SSH
Yield	0.06^{NS}	0.21^{NS}	0.13^{NS}	0.68**	- 0.36*	- 0.38*

** Significant at 1% level * Significant at 5% level NS: Not significant

Simple Linear Regression Analysis

Simple linear regression analysis was carried out separately for each climatic factor to know the effect of weather parameters on the maize yield and the results are presented in Table 2. The regression coefficients pertaining to the weather parameter viz., rainfall was found to be significant at 1%. The result also revealed that there was a positive influence of minimum temperature, maximum temperature, relative humidity and rainfall on the yield of maize whereas evaporation and sunshine hours had a negative influence on the yield of maize. The fitting of the regression equation of individual weather parameters on the yield are depicted in Fig.1.

Multiple Linear Regression Analysis

Multiple linear regression analysis was carried out for all the six weather parameters to know the overall effect of weather parameters on the maize crop yield. The rainfall had positively high significant influence on maize whereas evaporation had negatively high significant influence on maize crop yield with an R^2 value of 0.77. The model was free from multicollinearity with all the Variance Inflation Factor (VIF) associated with the predictor showing a value below 3 and the results are presented in the Table 3.

Table -2: Estimates of the simple linear regression model relating the ground yield with weather parameters

Weather parameters	Intercept	Slope	t- value	SE	R^2
Minimum temperature	- 841.82	143.94	0.83 ^{NS}	173.28	0.03
Maximum temperature	-239.28	75.87	0.44 ^{NS}	171.81	0.07
Relative Humidity	603.87	17.26	0.42 ^{NS}	41.57	0.06
Rainfall	817.34	1.45	4.17 **	0.35	0.41
Evaporation	2423.92	-118.79	-1.38 ^{NS}	86.41	0.13
SSH	2785.42	-179.32	- 1.65 ^{NS}	108.83	0.14

** Significant at 1% level * significant at 5% level NS: Not significant

From Fig.1 the results also showed that maximum temperature, minimum temperature, relative humidity and rainfall had positive influence on maize whereas evaporation and sun shine hours showed negative influence on maize crop yield (The similar results were reported by Govinda, 2013).

Test for Randomness and Normality of error terms

In order to test the adequacy of the model, randomness of errors was verified using runs test. The results are shown in Table 4. From the analysis, it was confirmed that the error terms were randomly distributed (with the total number of runs being 16) for the model. The normality of error terms was checked by using normal probability plot (Fig.2). The plot indicated near normal type with points scattered on either side of the line.

CONCLUSION

The present study has demonstrated that maize yield had positive correlation with all the weather parameters except evaporation and sun shine hours. Further, it revealed that the rainfall had significant positive relation with maize crop yield except evaporation and sun shine hours. The regression results revealed that the minimum and maximum temperature, relative humidity and rainfall had positive influence on maize yield whereas evaporation and sun shine hours showed negative influence on maize crop yield. Further, the rainfall had positively high significant influence on maize whereas evaporation had negatively high significant influence on maize crop yield with an R^2 value of 0.77.

Table -3: Multiple linear regression of weather parameters on the yield of maize

Regression	Coefficient	SE	t value	VIF
Intercept	-3325.32	3981.16	-0.83^{NS}	-
Max.Temp	189.49	103.53	1.83^{NS}	1.79
Min.Temp	-21.27	112.92	-0.19^{NS}	2.05
RH	2.79	24.30	0.12^{NS}	1.68
Rainfall	1.614	.213	7.56**	1.15
Evaporation	-220.49	65.86	- 3.35**	2.07
SSH	-12.32	84.91	-0.14^{NS}	2.73
F	12.82**			
R^2	0.77			

** Significant at 1% level NS: Not significant

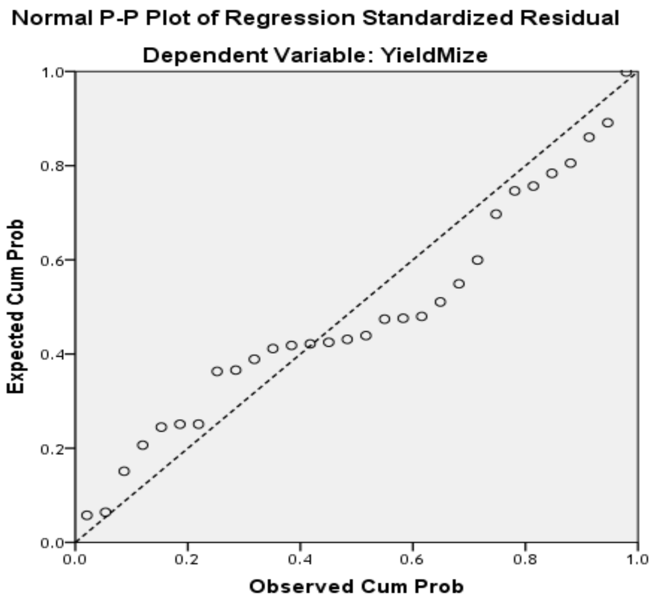


Fig.2 : Normal probability plot for maize crop yield

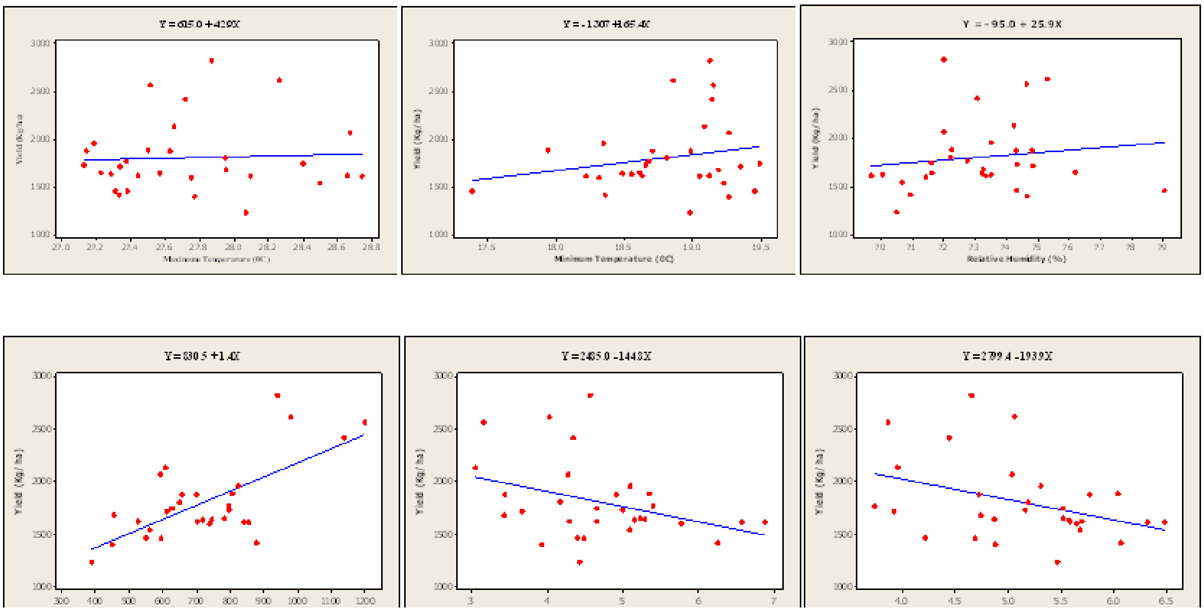


Fig.1 : Effect of weather parameters on maize crop yield

Table - 4: Observed and predicted yield of maize crop over the period of 30years (Period: 1984-2013)

Year	Observed Y	Predicted $\hat{Y}$	Residual $e_i = (Y - \hat{Y})$
1984	1416	1624.7	-208.7
1985	1598	1592.6	5.4
1986	1614	1655.8	-41.8
1987	1613	1683.9	-70.9
1988	1765	1714.0	51.0
1989	1886	1751.8	134.2
1990	1645	1680.1	-35.1
1991	1953	1778.9	174.1
1992	1732	1744.2	-12.2
1993	1651	1691.1	-40.1
1994	1637	1612.0	25.0
1995	1874	1624.6	249.4
1996	1459	1624.5	-165.5
1997	1745	1758.1	-13.1
1998	1714	1783.4	-69.4
1999	1401	1536.8	-135.8
2000	1876	1933.1	-57.1
2001	1462	1507.2	-45.2
2002	1537	1575.3	-38.3
2003	1230	1369.8	-139.8

2004	1621	1516.5	104.5
2005	2415	2550.8	-135.8
2006	1623	1930.8	-307.8
2007	2817	2202.3	614.7
2008	1805	1836.0	-31.0
2009	2613	2472.2	140.8
2010	2565	2883.9	-318.9
2011	1676	1686.2	-10.2
2012	2068	1849.0	219.0
2013	2134	1975.2	158.8
Run Test Statistic	No.of runs(r) = 16^{NS}, Critical Values : $r_L = 14, \quad r_U = 16$		

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