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# Statistical Analysis of Effect of Climatic Factors on Sugarcane Productivity over Maharashtra

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**Abstract-** This study estimates the effect of climatic factors on sugarcane productivity in Maharashtra. The main aim of this study is to analyze the climatic variability and its effect on sugarcane productivity over Maharashtra. This study utilized time series data for the 20 year period 1993-2013 corresponding to 33 rain gauge stations in Maharashtra. The data required for analysis is collected from Indian Meteorological Department (IMD) Pune. During observations and analysis of data some results are observed through MATLAB software and Multiple Regression Model that expresses a response variable as an error term plus mean that is conditional upon various factors. The present study covers the spatial domain of the from Coordinates 18°58′N 72°49′E in latitude and from 18.96°N 72.82°E in longitude covering the mainland region of Maharashtra. This study focuses the main climatic factors i.e. average monthly rainfall, average minimum and maximum temperature which have a statistically significant impact on sugarcane productivity. The climatic effects for various factors on sugarcane productivity vary within different seasons. Thus we can conclude that there is non-linear relationship between above mentioned climatic factors and sugarcane productivity in Maharashtra.

**Keywords:-***climatic variability, Indian Meteorological Department (IMD), Sugarcane productivity, Multiple regression Model.*

## 1. INTRODUCTION

It is generally observed that, among all sectors agricultural sectors or agriculture production activities are most sensitive and vulnerable to climate change (T Deressa, R Hassan, D Poonyth, and Dec 2005). Climate change is a direct input to the agricultural production process, so the agricultural sector has been a natural focus for research. Sugarcane is most important crop in Maharashtra. It has an important position in agrarian economy of Maharashtra well as in India. Sugarcane belongs to bamboo family of plant and it has indigenous to India. It is the main source of sugar, gur and khandasari, About two-third of total sugarcane production in Maharashtra consumed for making gur and khandsari, and one third of it goes to sugar factories. Approximately 7.5% rural population gets their basic livelihood resources, directly or indirectly, from sugar industries. In addition to this it gives some fuel as a byproduct along with a large number of high- costs, value-added products (Shrivastava et al., 2011). It is second largest agro-processing industry, cost almost Rs. 3000 crore after textiles India. This study provides evidence on the impact of climate change on agriculture in India, where poverty and agriculture are both salient. Climate change is likely to reduce agricultural yields significantly, and that this damage could be severe unless adaptation to higher temperatures is rapid and complete.

Climate plays an important role in all the phases of the sugarcane plant. Since, the plant stands in the field for 12-24 months, hence, goes through all possible limits of weather parameters i.e. rainfall, temperature, sunshine, humidity etc. All these parameters have a role in plant growth, sugar yield, quality and content of juice etc. For good growth of plant and high production, specific weather conditions with suitable parameter are required.

**Rainfall: -** Rainfall is an important factor for good growth of sugarcane. The plant requires optimum rains during the vegetative growth as it encourages rapid cane growth, cane elongation and internodes formation. During ripening period, the rainfall should be less in order to have good quality juice,

less vegetative growth as well as reduction in the tissue moisture. Due to high rainfall, these conditions may be adverse. An average of 1200 mm evenly distributed rainfall in the range of 1100-1500 mm is optimum for higher yield. However, good productions are also being taken in the regions having a minimum of 600mm and a maximum of 3000mm rainfalls, which depends on adoptive measures, selection of varieties, farming methods (ICAR 2000).

**Temperature: -** Temperature is equally important similar to the rainfall as it is closely related to the growth and productivity of the plant. Its optimum range varies for different phase of the plant which has a severe effect on good growth of plant and recovery of sugar. An optimum temperature for sprouting (germination) of stem cuttings is 32°C - 38°C as it slows down below 25°C, reaches plateau between 30°C -34°C, and reduced above 35°C, whereas, practically stops when the temperature is above 38°C. Temperatures above 38°C reduce the rate of photosynthesis and increase respiration. During ripening period, a low temperature in the range of 12°C -14°C reduces vegetative growth rate and enrichment of sucrose in the sugarcane.

Broadly there are two distinct agro-climatic regions of sugarcane cultivation in India, viz., tropical and subtropical. Tropical regions shared about 45%-55% of the total sugarcane area and production in the country, respectively along with the average productivity of 77t/ha (2012-13). Subtropical region accounted for about 55% to 45% of total area and production of sugarcane with an average productivity about 63t/ha (2012-13). In tropical zone Maharashtra is a major sugarcane growing state covering about 9.5 lakh ha. Area with production of 61.32 million ton. In 2013-14, total sugarcane area in the state is 9, 36,498 hectors

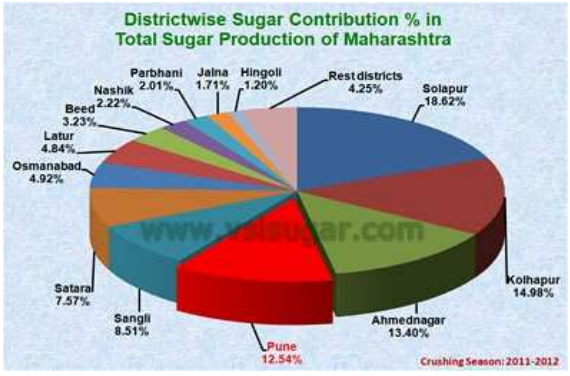



Fig 1 District wise sugarcane productions in Maharashtra (Source: Google Images)

which is slightly less than yearly average area because of climatic change (adverse situation of drought, uneven rainfall, and rise in temperature). Maharashtra contributed 0.58 million hectares (13.53%) to total area and 45.78% million tonnes (15.06%) to total production of sugarcane in country (GoI). In Maharashtra, Solapur (18.62%), Kolhapur (14.98%), Ahmednagar (13.40%), Pune (12.54%) are the major sugarcane production district.

## 2. LITERATURE REVIEW

This study consists of brief review of literature regarding climatic change and its impact of sugarcane productivity at global and national level. T Deressa, R Hassan, D poonyth (December 2005) analyze the impact of climatic change on South African sugarcane production under irrigation and dry land conditions .Data of 11 districts of South Africa and time series data for the period 1977-1998 is used for the study. This study used an econometric approach known as the Ricardian model to assess economic impact of climatic change. For this study, farm level data is used like price per ton, production per hectare, cost of labour, chemicals, fertilizer, fuels and lubricants, mechanical and fixture maintenance and irrigation per ton of sugarcane produced as well as climatic data like monthly average temperature and rainfall . This study results show that climatic change has significant non-linear impact on net revenue per hectare of sugarcane in South Africa with higher sensitivity to future increase in temperature than precipitation.

Raymond Guiteras, University of Maryland (September 2009) estimate the impact of climate change on Indian agriculture. To estimate effect of random year-to-year variation in weather on agricultural out he used 40 year district level data set covering over 200 Indian districts. For this study he selected data set from 1960-1999 i.e. 39 years. Yearly district level agricultural outcomes and yearly climate measures (temperature and precipitation) are used for this study. To study the impact, semi Recardian model, panel approach is used. Study observations show that climate change is likely to reduce agricultural yields significantly and that this damage could be served unless adaption to higher temperature is rapid and complete.

G.A.Gbetibouo, R.M.Hassan, University of Pretoria, South Africa (29 Oct 2014) carried out the study to measure the impact of climate change on South Africa field crops and to analyze potential

future impacts of future changes in the climate . For this study they used the data for seven field crops across 300 districts in South Africa. Ricardian model is used to study sensitivity of agricultural production to climate change. The factors used like topography, vegetation, temperature, rainfall and soil characteristics. This study used district level data on crop revenues for the year 1993. After study results indicates that production of field crops was sensitive to marginal changes in temperature as compares to changes in precipitation.

O. E. Ayinde, M. Muchie (University of South Africa), G. B. Olatunji (University of Nigeria), (2011), observed the effect of climate change on agricultural productivity in Nigeria. Descriptive and Co-integration analysis are the techniques used to analyze the time series data used in this work. For this work they used the annual data for rainfall, temperature from 1980 to 2006. This study shows that there is variability in Nigerian rainfall and temperature. The study also shows that the changes in climate have significant effect on agricultural productivity. It is recommended that if agricultural productivity was to be increased and sustained, environmentally and agricultural sensitive technologies and innovations that can prevent climate fluctuation should be encouraged.

Misheck Chandiposha, Department of Agronomy, Midlands State University P Bag 9055 Gweru, Zimbabwe. (Academic Journals, 20 June 2013) observed potential impact of climate change in sugarcane and mitigation strategies in Zimbabwe. This study reviews the possible effects of climate change in the agronomy of sugarcane. For this study they used data of temperature, rainfall. After study it is observed that sugarcane production affected by climate change climate change due to projected increase in temperature and changing rainfall patterns. The study also expounds on the mitigation and adaptation strategies that can be employed in the sugarcane industry as a way of reducing losses in sugarcane production**.**

Ajay Kumar and Pritee Sharma (June 2014) carried out the study for the understanding of relationship between climatic factors and sugarcane productivity. The main objective of the study is to estimate the impact of climatic and non- climatic factors on sugarcane productivity. For their study, the climatic factors like average rainfall, average maximum temperature, average minimum temperature and non-climatic factors like irrigated area, agriculture labour, consumption of fertilizers, literacy rate, tractors and farm harvest price etc.is used. Thirteen major agricultural states like Bihar, Orissa, Uttar Pradesh, Punjab, Haryana, Gujarat, Madhya Pradesh, west Bengal, Maharashtra, Rajasthan, Andhra Pradesh, Tamilnadu, and Karnataka are focused in this study. The data set for study covers 30 years at state level panel data during 1980-2009.To check the consistency of empirical result they selected simple linear regression model, Recardian productivity regression (non –linear) model and Cobb-Douglas production function model. The soft wares like C++, SPSS, and Minitab STATA was used. This study concluded that there is non-linear relationship between climatic factors and sugarcane productivity in India.

Aravind Moorthy, Wolfgang, Rajagopal (June 12, 2012) observed the climate change impacts on Indian agriculture. For their study they selected five major seasonal crops from 32 regions of India like rise, wheat, sorghum, cotton and sugarcane. The period of study was 1961 to 2010 i.e. 50 years. For their study state level monthly precipitation and temperature is used. To estimate how climate trends have affected crop yields India, yield model, climate change model is selected. It is observed that temperature and precipitation changes have significant effect on yields, but these effects vary greatly across crop. From this study, clear effect on climate variables on yield that suggest that temperature and precipitation increases can be harmful in some ranges, and helpful in others is identified.

S.C.Mali, P.K.Shrivastava, H.S.Thakare, Navsari Agricultural University, Gujarat (July 10, 2014) analyze the impact of weather changes on sugarcane production. The crop productivity data of two locations of South Gujarat were collected for the study .To quantify the interrelationship between different whether parameters and yield of sugarcane , for seven years (2007-2013) mean meteorological data on maximum and minimum temperature, humidity, rainfall was analyzed. After study it was observed that due to climatic aberrations especially rainfall and maximum temperature affect productivity, sugar recovery and burning in sugarcane crop.

K. S. Kavi Kumar (Jan13, 2011) carried out the study on climate sensitivity of Indian agriculture: do spatial effects matter? , which contributes to current knowledge of climate change

impacts on Indian agriculture by accounting for spatial features that may influence the climate sensitivity of agriculture. For this study 20 years period data on 271 districts in India was used. This paper contributed to existing knowledge on the impacts on climate change on Indian agriculture by climate change on Indian agriculture by accounting for spatial issues in Ricardian frame work.

Above discussion represents that climate change is very harmful for agricultural sector. Many studies give the clear evidence that it decreased the agricultural productivity in different regions of India and other countries of the world. In India, productivity of various crops are affected due to climate change. Hence present study tries to fill this research gap and provide a scientific understanding about climatic factors and its effect on sugarcane productivity in Maharashtra.

## 3. METHODOLOGY

**Source and Data Description: -** The data set for present is covering 20 years at state level panel data during 1993-2013. As Maharashtra state having second highest area (17.52%) in sugarcane production so Maharashtra state is taken from different agro ecological zones. To identify the missing values in the data set, interpolation method is used. The data for agricultural and climatic variables are taken from following sources:-

1. **Agricultural Data:-** Sugarcane production data was taken from Indian Institute of Sugarcane Research, Lucknow site as follow:- www.iisr.nic.in/servicesfacilities/maharashtra.html
2. **Climatic variables: -** For this study we used climatic variables as rainfall, min temperature, max temperature.

- **Rainfall data: -** This data was obtained from Indian Meteorological Department (IMD) (Government of India). This data was in the form of rainguage station wise monthly data over Maharashtra.
- **Min. Temperature: -** This data was obtained from Indian Meteorological Department (IMD) (Government of India). This data was in the form of monthly minimum temperature over Maharashtra.
- **Max. Temperature**: - This data was obtained from Indian Meteorological Department (IMD) (Government of India). This data was in the form of monthly maximum temperature over Maharashtra.

Average minimum temperature and average maximum temperature and average rainfall in three weather seasons like rainy, winter and summer are incorporated for regression analysis. Regression analysis is run by MATLAB software to fit the proposed model.

**Multiple Linear Regression Model: -** A linear regression model that contains more than one predictor variable is called Multiple Linear Regression Model.

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots \beta_p x_p + \varepsilon$$

For this study y is sugarcane production. $x_1, x_2, x_3$ are the rainfall data, minimum temperature, maximum temperature respectively. $\beta_0, \beta_1, \beta_2, , \beta_3$ are the estimated regression coefficient obtained from data set. $\varepsilon$ is the error term.

**Matlab: -** Matlab is a programming language developed by Math works. For determination of relationship between climatic factors and sugarcane productivity using Multiple Linear Regression model and for generation of various results (Graphs) MATLAB software is used.

### RESULTS AND DISCUSSIONS

***Table 1-Values of β***

| Values of β |
|---|
| **β0 =** 1.1372 |
| **β**1 = 0.0013 |
| **β**2 = 0.0607 |
| **β**3 = -0.1347 |

***Table 2-Regression output***

| | | |
|---|---|---|
| Dependent Variable:- Y | SSE = 7939436799.50163 | f = 0.653245973034536 |
| | DFE = 15 | $R^2$ = 0.0702023070858611 |
| | MSE = 529295786.633442 | |

*Note: SSE = sum of squared errors;*
*DFE = degrees of freedom associated with the error term;*
*MSE = mean square error; t-stat = t-statistic*;

Beginning with the lower portion of Table 2, note that the parameter estimates, the standard errors, and the *t*-statistics match the values given in equation. The variable "Intercept" refers to the constant term $\beta 0$ in the regression.

The top portion of Table 2 provides data

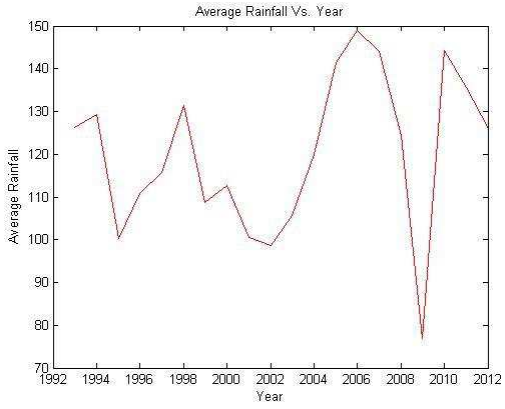
| Variable | Coefficient | Standard Error | tStat | P Value |
|---|---|---|---|---|
| Intercept | 1.07E+19 | 9.52E+18 | 1.1208 | 0.28002 |
| X1 | 133.72 | 238.07 | 0.5617 | 0.58262 |
| X2 | 5899.7 | 17464 | 0.33781 | 0.74019 |
| X3 | -13659 | 17069 | -0.8002 | 0.43607 |

that relate to the goodness-of-fit of the regression equation. The *sum of squared errors* (SSE) measures the sum of the squares of the regression residuals—the sum that is minimized by the least squares procedure. The degrees of freedom associated with the error term. (DFE) is given by the number of observations minus the number of parameters that were estimated. The *mean square error* (MSE) measures the variance of the error term (the square of the standard error of the regression). MSE is equal to SSE divided by DFE. The $R^2$ of .070 indicates that 7.0% of the variation in sugarcane production is explained by the regression variables, *X*1, *X*2, and *X*3.

***Table 3- Regression results***

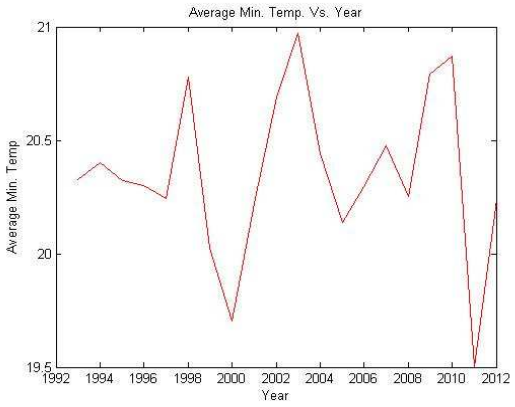
| Year | Regression Model Values | Error |
|---|---|---|
| 1993 | 5.305 | -2.5158 |
| 1994 | 4.9903 | -0.5643 |
| 1995 | 4.8915 | -0.2259 |
| 1996 | 5.2608 | -1.0803 |
| 1997 | 5.4271 | -1.6097 |
| 1998 | 4.3313 | 0.3838 |
| 1999 | 5.4167 | -0.1024 |
| 2000 | 5.9214 | -0.9625 |
| 2001 | 5.1262 | -0.6122 |
| 2002 | 4.7574 | -0.4957 |
| 2003 | 4.5256 | -1.9588 |
| 2004 | 5.351 | -3.3035 |
| 2005 | 5.6356 | -1.7503 |
| 2006 | 5.4053 | 2.4515 |
| 2007 | 5.0332 | 3.8105 |
| 2008 | 4.5019 | 1.5629 |
| 2009 | 5.4157 | 1.0002 |
| 2010 | 5.0289 | 3.1607 |
| 2011 | 6.2104 | 2.4629 |
| 2012 | 5.7003 | 0.3487 |

- **Trend of Rainfall:-**

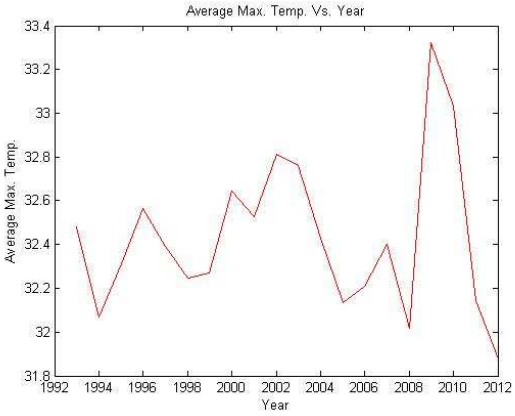



There is an occurrence of rainfall variability and unreliability in the state especially during the years studied. The period of 2000-2002 and 2007-2009 experienced the decreasing rainfall 100 mm and 77 mm respectively while the highest is 149 mm experience around 2006. This implies there is evidence of climate change. Graph 1 reveals the variability in this climate variable (rainfall).

- **Trend of Temperature:-**



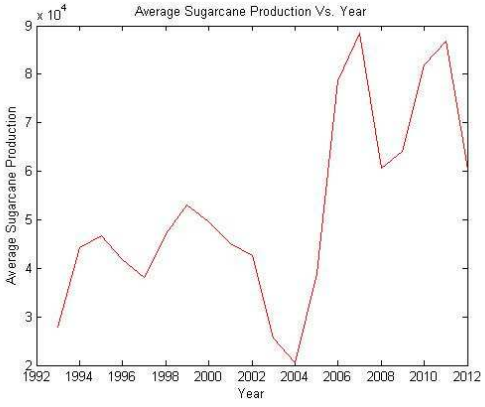
***Graph 2-Avg Min. Temp. Vs. Year***




***Graph 3-Avg Max. Temp. Vs. Year***

The average temperature during the study period is 26.36˚C, while the maximum and the minimum are 33.33˚C and 19.50˚C respectively. Graph 2 and Graph 3 shows that temperature is not relatively constant. There is a sharp reduction in the annual temperature in year 2000 and since then it has been experiencing unsteady trend. There is variation in the temperature variable.

- **Trend of Sugarcane Productivity:-**




***Graph 4-Avg Sugarcane Production Vs. Year***

The study reveals that there are continuous increase and decrease rates in agricultural productivity between 1993 and 2013 in the study area (Graph 4). This may be due to various climatic and non-climatic factors. Graph 4 further reveals that a much lower rate was experienced in agricultural productivity in the 2002–2004 sub periods. In fact sharp and great reduction is revealed in 2004. This implies a great variability in the agricultural productivity rate.

## 4. CONCLUSION

The main aim of this study is to analysis of climatic variability and its effect of sugarcane productivity in different weather seasons. Sugarcane productivity as dependent variables and other climatic factors as explanatory variables are compiled a panel data set for Maharashtra state during 1993-2013.After calculation; it is observed that climatic factors have a non-linear relationship with sugarcane productivity.

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