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Development of Statistical Model to Analyse the Growth in Area and Production of Sugarcane in India

Siddu Hanabar*, Y. N. Havaldar, K. V. Ashalatha, D. K. Vinay and Anand

Department of Agricultural Statistics, College of Agriculture, UAS, Dharwad-580005, Karnataka, India

**Corresponding author*

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A B S T R A C T

The present study was undertaken to analyse the growth rate in area and production of sugarcane in India. The study was based on secondary data from 1990-91 to 2014-15. The data was collected from different sources viz., Directorate of Economics and Statistics (DES) and website. To analyse the trend of area and production of sugarcane, Linear and Non-linear regression models were used. As a part of it six models were fitted to the area and production of sugarcane crop and the best models were selected based on highest co-efficient of determination (R^2) which explained the variation in dependent variable by the independent variables, least mean square error and standard error. Results revealed that exponential model was showed significantly best fit for predicting in both area and production of sugarcane based on time period. The exponential model was found to be best fit with highest R^2, least mean square error and standard error. Quadratic and cubic models were also found to be the best fit for predicting area and production of sugarcane.

Introduction

Sugarcane is one of the world's most important commercial crops. Sugarcane is a natural agriculture resource that provides sugar, biofuel, fibre, fertilizer and by-products or co-products. White sugar, brown sugar (Khandsari), jaggery (Gur) and ethanol are all made from sugarcane juice. Bagasse and molasses are the main by-products of the sugar industry. Globally, sugarcane is cultivated over an area of 27.12 million ha with a production of 1,884.24 million tonnes and productivity of 69.46 t ha^{-1} (Anon., 2015a).Sugarcane area and productivity differs widely from country to country. India ranks second among the sugarcane growing countries of the world in both area and production after Brazil. Area under sugarcane cultivation in India during 2014-15 was 5.01 million ha and production was 352.14 million tonnes with an average yield of 70.25 t ha^{-1}. The average productivity of sugarcane in India was about 70.00 t ha^{-1} While, the sugar recovery is around 10.37 per cent(Anon., 2015b).It is the prime source of sugar and one of the most promising commercial crops in India.

Statistical modelling is useful for predicting the underlying relationships between crucial variables in an agricultural system. Data analysis is important because it forms the basis for economics and policy planning by the governments. It becomes easy to formulate and initiate appropriate policy measures if the data with regard to the trend (increase or decrease) of the production is obtained and analyzed in advance. Growth rate analysis is commonly used to analyze long-term trends in various agricultural crops. The main feature of a statistical model is that variability is interpreted by probability distributions, which form the building-blocks from which the model is constructed.

In the present study, taking as area and production of sugarcane in India as dependent variables and time period as independent variable, non-linear and polynomial models were attempted.

Materials and Methods

The present investigation was based on secondary data which were collected from different sources viz., Directorate of Economics and Statistics (DES) and *www.indiastat.com.*The data include information like area and production of sugarcane for the period of 1990-91 to 2014-15. Fitting a linear equation to the variables under analysis is the easiest way to describe any relationship. However, it is possible that the relationship would not always be linear. In the present study, taking as area and production of sugarcane in India as dependent variables and time period as dependent variable, non-linear and polynomial models were attempted (Gomez and Gomez 1958). The model which showed relatively highest R^2, standard error and least mean square error (MSE) was chosen to fit a trend equation. Following models fitted to the data.

Linear model

$Y = b_0 + b_1(t)$ is the linear form of the model.

Y and tare dependent variable and time period (independent variable), respectively.

b_0 and b_1 are constants to be estimated.

Logarithmic model

The form of the model is

$Y_i = b_0+b_1 \, ln(t) + e_i$

Where,

Y_i is dependent variable and t_i's are independent variables.

b_i's are constants (where i=0 and 1) to be estimated and *ln* is natural log

and e_i is the random error.

Quadratic model

The form of the equation is,

$Y = b_0 + b_1 t + b_2 t^2 + e_i$

Where,

Y_i is dependent variable and t_i's are independent variables.

b_i's are constants (where i=0,1 and 2) to be estimated and e_i is the random error.

Cubic model

Here the equation is,

$Y = b_0 + b_1 t + b_2 t^2 + b_3 t^3 + e_i$

Where,

Y is dependent variable and t_i's are independent variables.

b_i's are constants (where i= 0, 1, 2 and 3) to be estimated and e_i is the random error.

Exponential model

Model under consideration is,

$Y = b_0 \times e^{(b1 * t)}$

Or

$ln(Y) = ln(b_0) + (b_1 t)$

Where,

Y_i is dependent variable and t_i's are independent variables.

b_i's are constants (where i= 0 and 1) to be estimated and *ln* is natural log and 'e_i' is the exponential function.

Power model

It has the form,

$Y = b_0 t^{b_1}$

On transformation,

$ln(Y) = ln(b_0) + b_1 ln(t)$ is obtained which is of the linear form

Where,

Y is dependent variable and t's are independent variables.

b_i is a constant to be estimated, i= 0 and 1 and *ln* is natural log.

Results and Discussion

From the non-linear regression model analysis, it is evident that, different models used to predict sugarcane area with the help of time period. For predicting sugarcane area with respect to time period, all the models were found to be significant.

Among all models selected the exponential model was found to be best fit with highest R^2 (co-efficient of determination) of 67.60 per cent, least mean square error of 0.005 and standard error of 0.071.

The quadratic and cubic models were also showed significantly best fit for predicting the sugarcane area with least mean square error of 0.098 and 0.103 along with their standard error values were 0.313 and 0.320 respectively where as the co-efficient of determination (R^2) was quite high as compared to exponential model.

Linear model was also found to be good fit as it is easy for prediction.

Exponential model $\hat{y}=3.5991e^{0.0132t}$

y= sugarcane area.

t= time period.

Table.1 Different statistical models with their equations for predicting the sugarcane area

Models	Equation	R^2	MSE	SE
Exponential	$\hat{Y}=3.5991e^{0.0132t}$	0.676	0.005	0.071
Linear	$\hat{Y}=3.56+0.0573t$	0.680	0.094	0.307
Logarithmic	$\hat{Y}=3.2109+0.4767\ln(t)$	0.564	0.128	0.358
Quadratic	$\hat{Y}=3.6016+0.0484t+0.0003t^2$	0.681	0.098	0.313
Cubic	$\hat{Y}=3.5741+0.0596t-0.0007t^2+0.000003t^3$	0.681	0.103	0.320
Power	$\hat{Y}=3.3098t^{0.1113}$	0.575	0.007	0.082

Y = Sugarcane area
t = Time period

Table.2 Different statistical models with their equations for predicting the sugarcane production

Models	Equation	R^2	MSE	SE
Exponential	$\hat{Y}=238.166e^{0.015t}$	0.599	0.009	0.097
Linear	$\hat{Y}=4.495t+234.536$	0.617	762.918	27.621
Logarithmic	$\hat{Y}=207.57+37.201\ln(t)$	0.507	982.215	31.340
Quadratic	$\hat{Y}=244.96+2.2614t+0.0827t^2$	0.627	776.592	27.867
Cubic	$\hat{Y}=229.25+8.6469t-0.4975t^2+0.0143t^3$	0.639	785.679	28.030
Power	$\hat{Y}=216.4t^{0.1273}$	0.510	0.011	0.107

Y= Sugarcane production
t= Time period

Fig.1 Exponential model for area of sugarcane from 1991 to 2015

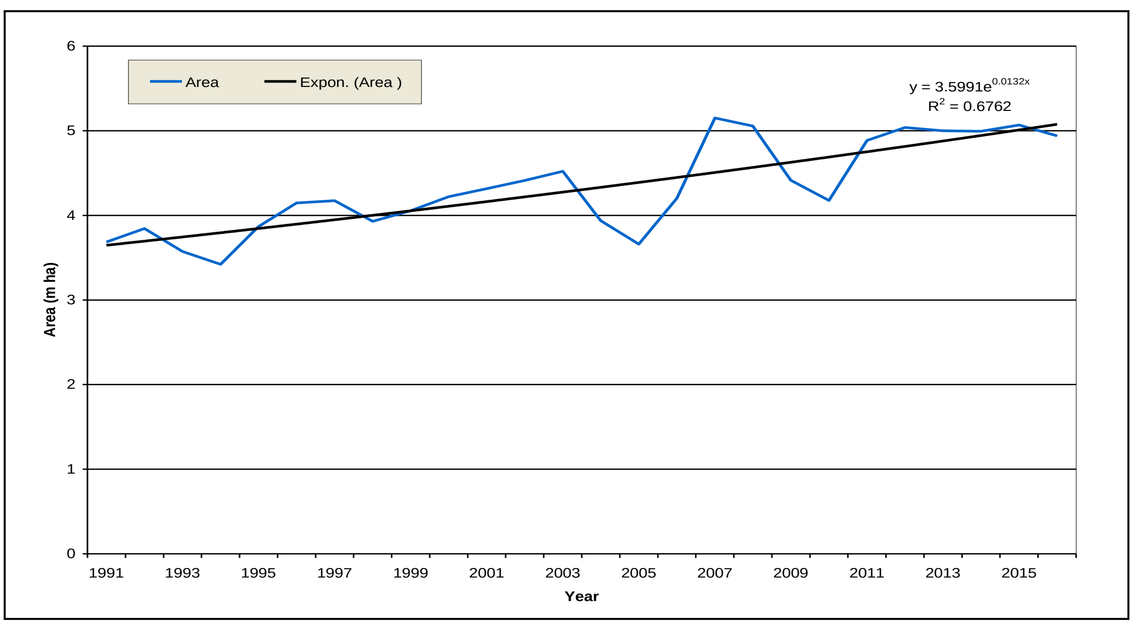
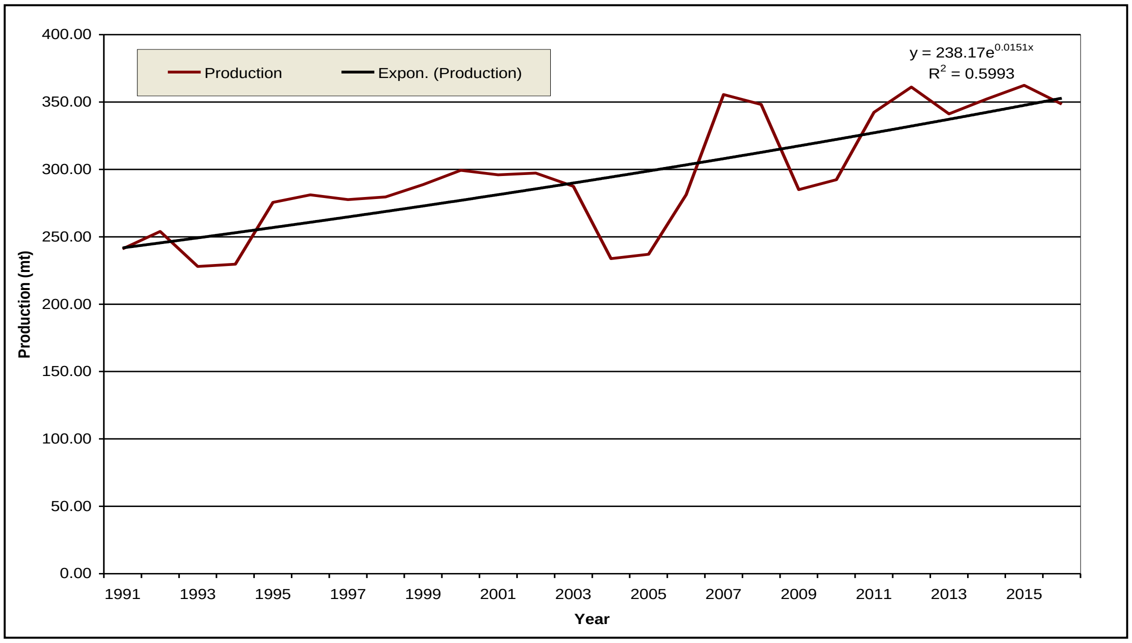


Fig.2 Exponential model for production of sugarcane from 1991 to 2015



The results revealed that, different linear and non-linear models used to predict sugarcane production with the help of time period.

For predicting sugarcane production with time period exponential model was found to be best fit with highest R^2 (co-efficient of determination) of 59.90 per cent, least mean square error and standard error of 0.009 and 0.097 respectively.

The cubic and quadratic models were also showed significantly best fit for predicting the sugarcane production with co-efficient of determination (R^2) of 63.90 per cent and 62.70 per cent respectively where as the standard error and least mean square were quite high compared to exponential model.

Exponential model $\hat{y}=238.166e^{0.015t}$

y=sugarcane production.

t=time period.

The exponential model was found to be the best fit in both area and production of sugarcane with highest R^2 values of 0.676 and 0.599respectively. The results of the models were shown in the Table.1 and 2; Fig.1 and 2. These results were on par with the study conducted by Bajpai *et al.,* (2012) and Therthappa (2005) who observed that, cubic model was significant and better in predicting seed yield in sunflower based on head diameter and disease at first stage.

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