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Influence of area and yield on the production of sugarcane in Durg district of Chhattisgarh in India

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Abstract
Predictive models for the sugarcane crop (*Saccharum officinarum*) in Durg district of Chhattisgarh have been made. Models have been fitted for the area, productivity and production of the crop separately for above district. Based on these models prediction of area, productivity and production of sugarcane have been made year wise between 1998-99 to 2012-13. The partial compound growth rates of the area, production and productivity of the crop have been also estimated and discussed. Periodic effect of five years as well as annual effects was found to be working in the district based on a postulated and estimated production function of area and productivity. It was found that the major influencing factor on the production of sugarcane was its area. This influence of area was around 89 per cent and productivity was around 11 per cent.

Keywords: Area, Growth rates, Prediction models, Production function, Sugarcane

Introduction
Sugarcane can be called as energy crop. Sugarcane is in great demand for various other uses like fodder, paper production and most importantly bio-fuels. It is also utilized in commercial gur and khandsari making. Sugar is a white gold is extremely essential and which is very valuable for the nation's food requirements and for economic development. Sugar is one of the most important commodities; produced and consumed around the world. In India, sugarcane is grown over 4 million ha of land. India is the second largest producer of sugar in the world after Brazil and it produces approximately 22 million tonnes of sugar annually and sugar recovery percentage around 10.25% during 2011-12. Sugar production in the country like India in some years there was surplus production and during next year of surplus production, the production of sugar was deficit than requirement. Thus the sugar production in India is widely fluctuating [1].

A cash crop helps sustain a community's economy with a marketable agricultural product. Cash crops are those which are produced for the purpose of generating cash or money [2]. Sugarcane belongs to bamboo family of plants and is indigenous to India. It is a long duration crop and requires 10 to 15 and even 18 months to mature, depending upon the geographical conditions. It requires hot and humid climate with average temperature of 21-27°C and 75-150 cm rainfall.

The rainfall in Chhattisgarh is the only factor that drives the sugar industry in Chhattisgarh. Till now, from 1998, the state has witnessed a healthy growth in the sugar industry due to the good monsoon experienced. Both the sugar factories that are located in Chhattisgarh have a crushing capacity of around 2500 TCD (tonnes crushed per day). The cooperative sugar factories of Chhattisgarh have produced 68,196 metric tons of sugar in fiscal 2013-14 [3].

Some of the districts of Chhattisgarh are also cultivated sugarcane predominantly and catching the area in Kabirdham (Kawardha), Ambikapur and Balod districts. About two-thirds of the total sugarcane produced in India is used for making gur and khandsari and one third of its goes to sugar factories. The total area of sugarcane cultivation in the Chhattisgarh state was around 3.49 thousand hectares in 2001-02 which increased to 30.12 thousand hectares in 2015-16. However, the total production of sugarcane in the state is 8.98 thousand tonnes in 2000-01 that increased to 46.90 thousand tonnes in 2015-16.

In view of this sugarcane is being promoted at farmers' fields in Durg division (Kabirdham and Balod districts) of Chhattisgarh to meet out the requirement of sugar mill [4].

In this view the present study is undertaken to analyze changes in area, production and productivity of sugarcane in Durg district of Chhattisgarh. The specific objective was:

1. To develop predictive models for the area, production and productivity of Sugarcane in Durg district of Chhattisgarh.
2. To assess the growth rate in area, production and productivity of Sugarcane in Durg district of Chhattisgarh.
3. To assess the level of influence contributed by area and productivity towards production of Sugarcane in Durg district of Chhattisgarh.

Materials and Methods

The time series secondary data on area, production and productivity of Sugarcane for Durg district of Chhattisgarh were collected for the Period from 1998-99 to 2012-13 from 'Basic Agricultural Statistics' published by Commissioner of Land Records and Settlement, Raipur, Chhattisgarh [5, 6] and from the web site of Chhattisgarh Government www.agrideptcg.gov.in [7].

A prediction analysis will be done so as to find out any Periodic effect present in the data for a given response variable for Durg district of Chhattisgarh. This Periodic effect will be taken as structural effect acting on the area, production and productivity of the Sugarcane indicating some technical research breakthrough.

After fitting such structural Periodic effects, Periodic effect variable P and annual effect variable T will also be introduced to measure the Periodic trend and annual trend respectively within each Period. The following multiple regression model will be fitted using step wise regression technique as described [8, 9].

$$\ln Y = Int + b_P P + b_t T + \varepsilon \quad \ldots\ldots (1a)$$

$$\hat{\ln} Y = Int + b_P P + b_t T \quad \ldots\ldots (1b)$$

Where,

$\hat{\ln}$ Y= expected value of the natural logarithm of the response variable (Y): area, productivity (*i.e.* yield) or production of given district;

Int= intercept;

P = periodic time variable; taking values from 1 to 3 signifying Pd I, i.e., first period for 1998-99 to 2002-03, Pd II for 2003-04 to 2007-08 and Pd III for 2008-09 to 2012-13.

T = annual time variable; taking values from 1 to 5 signifying the 1st, 2nd, 3rd, 4th or 5th, year for any period 1 to 3.

b_P = partial linear regression coefficient corresponding to variable P;

b_t = partial linear regression coefficient corresponding to variable T;

ε = error/disturbance component.

Now, in equation (1b) let T be fixed at a particular position in any Period, so that it may be considered constant within any Period while P varies, then we may write (1b) in the form.

$\hat{\ln}$ Y= C+ b_P P, where C= Int (since b_t = 0 for constant T) …… (2a)

or, $Y_x = a\, e^{\theta x}$, where Y_x = Y, a = e^c, θ = b_p, x = P …… (2b)

Again, on putting x=0 and 1 respectively we get Y_0=a and Y_1= a e^{θ} = Y_0 (1+r_1), where (1+r_1) = e^{θ}, say.

Then we have% r_1= {(Y_p – Y_{p-1})/Y_{p-1}} 100 for fixed T. Also, r_1=e^{θ} -1 =1 + θ-1= θ =b_p (higher powers of θ in e^{θ} may be ignored). Therefore, r_1 may be defined as the proportional rate of growth in response variable Y per unit change of P for fixed T, *i.e.*, a partial compound growth rate. Similarly r_2 and b_t can be interpreted with respect to variable T.

Lastly, our interest is to find the extent of influence of area and productivity on the production of sugarcane in Durg district of Chhattisgarh. For that we need an additive model with and error term. We have the identity, Production= Area x Productivity.

However, in actual practice the area, production and productivity are not always reported to be accurate enough to equal to above product, due to probably rounding errors and many a times due to human error in recording the data. Therefore, assuming that the actual area, production and productivity are some powers of the reported data and representing the residual discrepancies with an error term, this identity can be written in the functional form. Then, after taking natural logarithms, denoting the error component by $\in' \sim$ N (0, σ_ϵ^2) and then introducing the intercept term we can have the following linear statistical model:

$$\text{In P (A, Y)} = c_0 + c_1 \text{ In A} + c_2 \text{ In Y} + \in' \quad \ldots\ldots (3a)$$

$$\text{Or, } \hat{\text{In}} \text{ P (A, Y)} = c_0 + c_1 \text{ In A} + c_2 \text{ In Y} \quad \ldots\ldots (3b)$$

$$\text{Or, } \hat{P} \text{ (A, Y)} = d_0 A^{c1} Y^{c2},\ d_0 = e^{c0} \quad \ldots\ldots (3c)$$

Where, A, Y and $\hat{P}$ (A, Y) denote the area, productivity and estimated production of a given region, the constant c_0 is the intercept and (c_1, c_2) are the partial regression coefficients corresponding to variables In A and In Y respectively [10].

Results and Discussions

Partial compound growth rate of area, production and yield of sugarcane was for period (1998-99 to 2012-13) and presented in Table 1. It was observed that from the Table 1 Durg district of Chhattisgarh had registered statistically significant increasing periodic partial compound growth rate in production (146.787 per cent) at 1 per cent level but area (11.928 per cent) and productivity (8.094 percent) was non-significant.

The annual compound growth rate for area, productivity and production were found (3.893 per cent), (4.187 percent) and (24.534 per cent) non-significant respectively.

The model showed highly significant partial regression for the periodic variable production for Durg district (0.903) at 1 per cent level. But the model showed non-significant partial regression coefficient for time variable.

Table 1: Prediction models (w.r.t. time) of area and production under sugarcane for Durg district using model (1) for period 1998-99 to 2012-13

District		Int	bp	%r_1 @	bt	% r_2 @	% R^2
Durg	A	0.606	0.113	11.928	0.038	3.893	0.123
	Y	7.080	0.078	8.094	0.041	4.187	0.035
	P	-1.651	0.903***	146.787***	0.219	24.534	0.805***

*significant at 10% level, ** significant at 5% level, *** significant at 1% level

@% r_1 and @% r_2 indicate the partial compound growth rates (in percentages) corresponding to bp and bt respectively

A: Area in 000' ha, Y: Yield in Kg/ha, P: Production in 000' tones

Production function

To know the extent of influence of area and productivity on the production of Sugarcane the postulated production function is given by equations 3(a), 3(b) and 3(c). The estimated production in terms of area and yield for the period has been presented in Table 2.

It revealed from Table 2 that for Durg district the production function satisfactorily fits to the data as indicated by more than 90%. The column designated (1) and (2) gives the breakup of the total percent sum of squares explained by the production component, ln P (A, Y) in to its percent sum of square explained by the area component ln A and the yield component ln Y. These columns (1) and (2) showed that in Durg district the area influences the production and only a little contribution is made by the productivity of sugarcane.

Table 2: Production function as influenced by the area and productivity of sugarcane in Durg district for period 1998-99 to 2012-13

District		Production Function			Area Effect (1)*	Yield Effect (2)$	Total (3)@
		Int	ln A	ln Y			
Durg	ln P (A, Y) =	-7.080	0.980	1.026	88.973	10.237	99.210

*percent sum of squares explained by ln A, i.e. area effect
$percent sum of squares explained by ln Y, i.e. yield effect
@ Total percent sum of squares explained by ln P (A, Y) i.e. by the model (3)

Prediction of area, yield and production for 2013-14 to2017-18

Table 3 gives a prediction of area, production and productivity of sugarcane crop for the future years (2013-14 to 2017-18) based on the prediction models estimated in the present study (Table 1) (fig. 1,2&3). It is expected that the productivity of sugarcane in Durg will increase from 1688 to 1990 kg/ha, {[(1990-1688)/1688)] 100 = 17.891%}, by the turn of this decade, if the present growth trend in productivity is maintained. Since the slightly increasing in area is going to be {[(3.483-2.989)/2.989] 100 = 16.527%}, the 17.891% rate of increases in productivity.

Table 3: Prediction of area, productivity and production under sugarcane crop for Durg district for 2013-14 to 2017-18*

District		Year					% Increase/Decrease
		2013-14	2014-15	2015-16	2016-17	2017-18	
Durg	A	2.989	3.106	3.227	3.352	3.483	16.527
	Y	1688	1759	1833	1910	1990	17.891
	P	8.867	11.042	13.751	17.125	21.327	140.521

*Predicted value = exp (Int + bp P + bt T), where Int = intercept; bp and bt the partial regression coefficient corresponding to P and T variables respectively.

For 2013-14 to 2015-16; T= 1 to 5 for fixed P= 4.
A: Area in 000' ha, Y: Yield in Kg/ha, P: Production in 000' tones

Conclusion

The periodic partial compound growth rate for production had found to be significant, while, for area and productivity had found to be non-significant, whereas the annual partial compound growth rate for area, production and productivity had found to be non-significant. The production function satisfactorily fits to the data indicating more than 90 per cent R^2 in Durg district. The production is influenced by area, i.e., due to technology and influence on production by productivity is very low. By prediction analysis, it was found that there will increase in production but a slight increase in area and productivity in future years.

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