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Growth Rate and Instability Analysis of Sugarcane in Selected States of India

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ABSTRACT

The present paper deals with the analysis of growth and instability in production, area and yield of sugarcane for some selected states of India by estimating compound growth rate (CGR) and Cuddy-Della Valle (CDV) instability index on the basis of time series data on production, area and yield of sugarcane pertaining to the period 2010-2019 for the concerned states. The statistical measures viz. percentage change and percentage share have also been incorporated in the study. The percentage change is used for exploring the trend pattern of sugarcane during the concerned period by considering the base year as 2010. Moreover, the values of statistical coefficients viz. coefficient of variation (CV) and coefficient of determination (R^2) have been obtained for the production, area and yield of sugarcane in the concerned states. The values of R^2 have been computed by fitting linear models to the respective time series data on production, area and yield of sugarcane in the concerned states.

HIGHLIGHTS

◎ The present study is based on secondary time series data on sugarcane pertaining to the period 2010-2019.

◎ The percentage change in production, area and yield of sugarcane has been computed for exploring the respective trend pattern of sugarcane in selected states of India.

◎ The percentage share of production, area and yield of sugarcane for the entire states of India in the year 2019 have been depicted graphically.

◎ The instability index developed by Cuddy-Della Valle is obtained in the study to measure the level of instability in production, area and yield of sugarcane.

◎ The compound growth rates (CGRs) for production, area and yield of sugarcane have been obtained in selected states of India.

Sugarcane (*Saccharum officinarum*) belongs to the Poaceae family, and grown widely in most of the states of India. It is one of the major cash crop of India, and is a potential source of vital nutrients such as calcium, phosphorous, amino acids and other multi-vitamins. The sugarcane juice is used in the manufacture of sugar, jaggery and pharmaceutical products. Jaggery is recognized as a healthier dietary substitute as compared to white sugar. The sugar industry is regarded as one of the largest agro-based industry providing lot of

employment opportunities, and hence contributing in the economic growth of the nation.

The agro-climatic regions for cultivation of sugarcane in India are classified into two specific regions: tropical and sub-tropical. The tropical region share about 45% and 55%, respectively, of the total area

and production of sugarcane in the country, with an average productivity of 77 tons per hectare (2011-12). The sub-tropical region share about 55% and 45% of the total area and production of sugarcane along with the average productivity of 63 tons per hectare (2011-12) [As per the records of Farmers' Portal, Govt. of India].

In India, the leading state in the production of sugarcane is Uttar Pradesh (178.42 million tons), followed by Maharashtra (64.67 million tons), Karnataka (31.60 million tons), and others including Andhra Pradesh (6.77 million tons). In India, the overall production of sugarcane was 355.70 million tons, and the sugarcane yield was 77.89 tons per hectare during the year 2019-20 [Source: Directorate of Economics & Statistics, DAC&FW, Govt. of India].

A lot of research works have been carried out by various scientists and researchers for exploring the significance and usefulness of sugarcane, for instance, the medicinal and nutritional benefits of sugarcane have been explored by Singh *et al.* (2015). The use of technologies for enhancing the income of sugarcane farmers, and suggestions for policy interventions has been described by Roy and Chandra (2019). The accuracy of nutritional diagnosis for phosphorus in sugarcane, as well as the optimum nutritional composition diagnosis (CND) criteria for sugarcane was determined by Pereira da Silva *et al.* (2020). The health benefits of jaggery have been explored by Rao and Singh (2022).

The percentage change and compound annual growth rate (CAGR) in area, production and yield of sugarcane in Uttar Pradesh was revealed by Arti and Rai (2017) on utilizing the secondary time series data on sugarcane pertaining to the period 1950-2015. The simple and compound growth rates for sugarcane production in the districts of eastern Uttar Pradesh were evaluated by Lal *et al.* (2020).

The factors responsible for instability in area, yield and production for major crops in India during the period 1950-1951 to 2001-2002 was examined by Larson *et al.* (2004). The concerned period was divided into a pre-Green Revolution and post-Green Revolution, with each period analyzed separately as well as jointly. The coefficient of variation (CV) was computed for both the periods, and percentage change in CV was obtained. The growth and trend of

pulse production in India was examined by Sharma *et al.* (2013) on using linear, semi-log growth function and compound growth function. In addition, the Cuddy-Della Valle index was computed to measure the instability in pulse production. The growth and instability in area, production and productivity of different crops in Bengaluru division in the state of Karnataka pertaining to the period 1998-99 to 2013-14 was analyzed by Patil and Yeledhalli (2016). The resource use efficiency in major sugarcane growing states of India and the performance of sugar trade was assessed by Ahmad *et al.* (2018), along with the growth and instability analysis in the area, production, and productivity of sugarcane.

The compound growth rate and instability of major crops in Nepal were examined by Joshi *et al.* (2021). The instability and decomposition analysis of sesamum crop production in Karnataka as well as in India was elaborated by Nayak *et al.* (2021). The spatial growth and instability in area, production and yield of sugarcane in major sugarcane growing states of India were investigated and evaluated by Singh *et al.* (2021). In addition, Student's t-test was incorporated for checking the significant differences in area, production, and productivity trends using compound growth rate (CGR).

In recent years, the time series analysis of agricultural crops has become indispensable for exploring the long term trend pattern of the crop, and policy formulation regarding bulk storage, price fixation, and transportation. Considering this fact, an attempt has been made in the present paper to analyze the growth and instability in production, area and yield of sugarcane for some selected states of India.

DATA AND METHODOLOGY

Source of Data

For the purpose of present study, the secondary time series data pertaining to the period 2010 to 2019, on production, area and yield of sugarcane in selected states of India is considered. The concerned time series data is obtained from Directorate of Economics & Statistics, DAC&FW, Govt. of India, and Indian Institute of Sugarcane Research, Lucknow.

Terminologies and Notations

For the present analysis, we have considered four

sugarcane growing states of India, namely, Uttar Pradesh (S1), Maharashtra (S2), Andhra Pradesh (S3), and Karnataka (S4). In these states, significant variations are observed in production, area and yield of sugarcane during the concerned period of study. In order to examine these variations, we have computed the Cuddy-Della Valle (CDV) instability index, compound growth rate, and other statistical coefficients which are elaborated in the subsequent sections.

Statistical Measures and Coefficients

(a) Percentage change in area, production and yield of sugarcane

% change in X =

$$\frac{\text{Value of } X \text{ in the current year} - \text{Value of } X \text{ in the base year}}{\text{Value of } X \text{ in the base year}} \times 100$$

where X = Area, Production, or Yield (as the case may be). The year 2010 is selected as the base year for the present study.

(b) Percentage share of area, production and yield of sugarcane in India

% share of X in state S_i =

$$\frac{\text{Value of } X \text{ in state } S_i}{\text{Overall Value of } X \text{ in India}} \times 100$$

where X = Area, Production, or Yield (as the case may be) for the given year.

(c) Coefficient of Variation (CV)

The coefficient of variation (CV) is expressed as:

$$CV(X) = \frac{SD(X)}{\overline{X}} \times 100 \,,$$

where $SD(X)$ denotes the standard deviation of the variable X (which may be either of area, production or yield, as the case may be). Also, $\overline{X}$ denotes the mean of the variable X.

(d) Instability Index

In order to measure the level of instability in production, area and yield of sugarcane for the selected states S1, S2, S3 and S4 of India, the Cuddy-Della Valle (CDV) instability index is used. The instability index is given by the formula:

$$I = CV\sqrt{1 - R^2}$$

where R^2 denotes the coefficient of determination, which is obtained on fitting linear model to the concerned time series data on production, area and yield of sugarcane for the respective states. Also, CV represents the coefficient of variation.

(e) Compound Growth Rate (CGR)

The compound growth rate (CGR) in production, area and yield of sugarcane is obtained by using the following function:

$$y_t = a(1+r)^t \qquad \ldots(1)$$

where y_t is the observed value of production, area or yield (as the case may be) of sugarcane at time t. Also, 'a' is a statistical constant, and 'r' denotes the compound growth rate.

From (1), we have,

$$\log y_t = \log a + t\{\log(1+r)\}$$

$$\text{i.e., } Y_t = A + Rt \qquad \ldots(2)$$

where $Y_t = \log y_t$, $A = \log a$, and $R = \log(1+r)$.

The normal equations for estimating 'A' and 'R' are given below:

$$\Sigma Y_t = nA + R\Sigma t \qquad \ldots(3)$$

$$\Sigma t Y_t = A\Sigma t + R\Sigma t^2 \qquad \ldots(4)$$

Finally, on solving (3) and (4), the estimated values of 'a' and 'r' are obtained as follows:

$$\hat{a} = \text{antilog}(A)$$
$$\hat{r} = \text{antilog}(R) - 1$$

Here, $\hat{r}$ denotes the compound growth rate (CGR), and is generally expressed in terms of percentage as follows:

$$\hat{r} = [\text{antilog}(R) - 1] \times 100$$

DATA ANALYSIS AND RESULTS

The secondary time series data on production, area and yield of sugarcane in the states S1, S2, S3 and S4 of India are demonstrated in Tables 1, 2, and 3 respectively. Moreover, the percentage change in production, area and yield of sugarcane for the selected states of India are depicted in Tables 4, 5 and 6 respectively.

Table 1: Time series data on production of sugarcane in selected states of India

Year	*Production (in million tons) for the states			
	S1	S2	S3	S4
2010	120.55	81.90	14.96	39.66
2011	128.82	86.73	16.69	38.81
2012	132.43	69.65	15.57	35.73
2013	134.69	76.90	15.39	37.91
2014	133.06	84.70	9.99	43.78
2015	145.39	77.37	9.35	37.83
2016	140.17	52.26	7.83	27.38
2017	177.03	82.98	7.79	31.14
2018	179.71	89.77	8.09	42.41
2019	178.42	64.67	6.77	31.60

*Sources: *Directorate of Economics & Statistics, DAC&FW, Govt. of India, and Indian Institute of Sugarcane Research, Lucknow.*

Table 2: Time series data on area under sugarcane cultivation in selected states of India

Year	* Area under cultivation (in '000 hectares) of the states			
	S1	S2	S3	S4
2010	2125	965	192	423
2011	2162	1022	204	430
2012	2212	933	196	425
2013	2220	940	190	420
2014	2140	1030	140	480
2015	2170	990	120	450
2016	2160	630	100	400
2017	2230	900	100	370
2018	2220	1160	100	470
2019	2210	820	90	400

*Sources: *Directorate of Economics & Statistics, DAC&FW, Govt. of India, and Indian Institute of Sugarcane Research, Lucknow.*

Table 3: Time series data on yield of sugarcane in selected states of India

Year	* Yield (tons/hectare) for the states			
	S1	S2	S3	S4
2010	56.75	84.87	77.94	93.75
2011	59.58	84.87	81.79	90.25
2012	59.88	74.66	79.42	84.08
2013	60.45	82.07	80.13	90.25
2014	62.15	82.23	71.85	91.20
2015	67.03	74.65	76.66	84.08
2016	64.89	82.52	76.02	68.96
2017	79.24	92.00	78.68	84.08
2018	80.81	77.20	79.36	90.00
2019	80.81	78.65	78.72	79.00

*Sources: *Directorate of Economics & Statistics, DAC&FW, Govt. of India, and Indian Institute of Sugarcane Research, Lucknow.*

Table 4: Percentage change in sugarcane production for selected states of India

Year	Percentage change (%) in production for the states			
	S1	S2	S3	S4
2010	—	—	—	—
2011	6.86	5.94	11.56	-2.19
2012	9.85	-14.93	4.08	-9.96
2013	11.73	-6.07	2.87	-4.46
2014	10.38	3.46	-33.22	10.33
2015	20.61	-5.50	-37.50	-4.66
2016	16.28	-36.17	-47.66	-31.00
2017	46.85	1.36	-47.93	-21.52
2018	49.08	9.65	-45.92	6.88
2019	48.00	-21.01	-54.75	-20.36

Table 5: Percentage change in area under sugarcane cultivation for selected states of India

Year	Percentage change (%) in area for the states			
	S1	S2	S3	S4
2010	—	—	—	—
2011	1.74	5.91	6.25	1.65
2012	4.09	-3.32	2.08	0.47
2013	4.94	-2.59	-1.04	-0.71
2014	0.71	6.74	-27.08	13.48
2015	2.18	2.59	-37.50	6.38
2016	1.65	-34.72	-47.92	-5.44
2017	4.94	-6.74	-47.92	-12.53
2018	4.47	20.21	-47.92	11.11
2019	4.00	-15.02	-53.13	-5.44

Table 6: Percentage change in sugarcane yield for selected states of India

Year	Percentage change (%) in yield for the states			
	S1	S2	S3	S4
2010	—	—	—	—
2011	5.02	0	4.94	-3.73
2012	5.55	-12.03	1.90	-10.31
2013	6.56	-3.30	2.81	-3.73
2014	9.55	-3.11	-7.81	-2.72
2015	18.16	-12.04	-1.64	-10.31
2016	14.38	-2.77	-2.46	-26.44
2017	39.68	8.40	0.95	-10.31
2018	42.45	-9.04	1.82	-4.00
2019	42.45	-7.33	1.00	-15.73

The percentage share of production, area and yield of sugarcane for the year 2019 in various sugarcane growing states of India are depicted graphically in Figs. 1, 2, and 3 respectively.
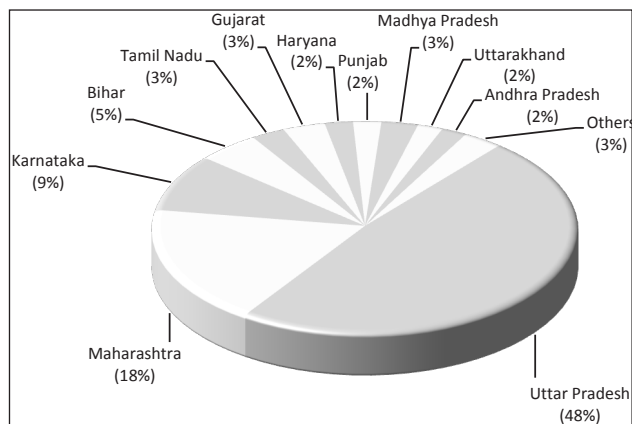

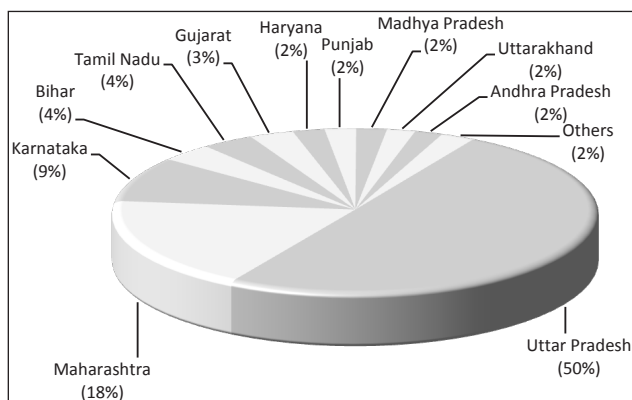**Fig. 1:** Percentage share of sugarcane production in the year 2019

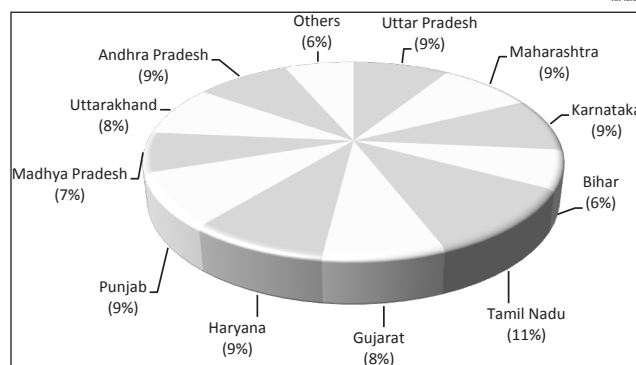**Fig. 2:** Percentage share of sugarcane area in the year 2019

Fig. 3: Percentage share of sugarcane yield in the year 2019

The values of various statistical measures, i.e., mean, variance and standard deviation (SD), for production, area and yield of sugarcane in the state S1, S2, S3, and S4 of India, are summarized in Table 7.

The values of various statistical coefficients, i.e., coefficient of variation (CV), coefficient of determination (R^2), and Cuddy-Della Valle instability index (I) for production, area and yield of sugarcane in the concerned states are summarized in Table 8. In order to compute the values of R^2 for production, area and yield of sugarcane in the concerned states, a linear model is fitted to the time series data on sugarcane.

The compound growth rates (CGRs) for production, area and yield of sugarcane in the concerned states of India, are computed and the findings are presented in Table 9.

Table 7: Values of various statistical measures for production, area and yield of sugarcane in the selected states of India

States	Production			Area			Yield		
	Mean	Variance	SD	Mean	Variance	SD	Mean	Variance	SD
S1	147.03	510.72	22.60	2184.9	425.87	37.76	67.16	90.34	9.50
S2	76.69	132.68	11.52	939.00	19832	140.83	81.37	28.34	5.32
S3	11.24	15.34	3.92	143.20	2225.96	47.18	78.06	7.47	2.73
S4	36.63	27.05	5.20	426.80	1107.96	33.29	85.56	54.19	7.40

Table 8: Values of various statistical coefficients for production, area and yield of sugarcane in the selected states of India

States	Production			Area			Yield		
	C.V.	R^2	I	C.V.	R^2	I	C.V.	R^2	I
S1	15.37	0.84	6.15	1.73	0.29	1.45	14.15	0.86	5.32
S2	15.02	0.06	14.59	15.00	0.04	14.72	6.54	0.01	6.51
S3	34.84	0.84	13.76	32.95	0.88	11.27	3.50	0.02	3.47
S4	14.20	0.15	13.13	7.80	0.03	7.70	8.60	0.26	7.39

Table 9: CGR (in percentage) for production, area and yield of sugarcane in selected states of India

States	Production	Area	Yield
S1	4.66	0.31	4.34
S2	-1.36	-1.20	-0.23
S3	-10.21	-9.93	-0.16
S4	-1.94	-0.47	-1.47

From Table 9, it is revealed that:

(i) In state S1, there is a rapid growth in production and yield of sugarcane during the period 2010-2019. Moreover, a steady growth in the area under sugarcane cultivation has been observed.

(ii) In state S2, there is a slight decline in production, area, and yield of sugarcane.

(iii) In state S3, a rapid decline in production as well as area under cultivation has been observed, whereas a slight decline in yield has been observed.

(iv) In state S4, negative growth rates in production, area and yield of sugarcane has been observed.

DISCUSSION AND CONCLUSION

In the present paper, the time series data pertaining to the period 2010-2019 on production, area and yield of sugarcane in the selected states S1 (Uttar Pradesh), S2 (Maharashtra), S3 (Andhra Pradesh) and S4 (Karnataka) of India is considered. The percentage change in production, area and yield of sugarcane has been evaluated, by considering the base year as 2010, for the selected states of India and the findings are explored in Tables 4, 5 and 6, respectively. From Table 4, it is revealed that for the year 2019, the percentage change in production of sugarcane is positively high for the state S1 (i.e., 48.00 %). However, the percentage change in production is negatively high for the state S3 (i.e.,-54.75 %), followed by the states S2 (i.e., -21.01 %) and S4 (i.e., -20.36 %). From Table 5, it is revealed that for the year 2019, the percentage change in area of sugarcane is positive for the state S1 (i.e., 4.00 %). In contrast, the percentage change in area is negatively high for the state S3 (i.e., -53.13 %), followed by the states S2 (i.e., -15.02 %) and S4 (i.e., -5.44 %). From Table 6, it is revealed that for the year 2019, the percentage change in yield of sugarcane

is positively high for the state S1 (i.e., 42.45 %) and the least for the state S3 (i.e., 1.00 %). Moreover, the percentage change in yield is negative for the states S4 (i.e., -15.73 %) and S2 (i.e., -7.33 %).

The percentage share for production, area and yield of sugarcane in the year 2019 for the sugarcane growing states of India have been demonstrated graphically in Figs. 1, 2 and 3, respectively. From Fig. 1, it is observed that the state Uttar Pradesh (S1) exhibits highest percentage share for sugarcane production (i.e., 48%), whereas the states Haryana, Punjab, Uttarakhand and Andhra Pradesh (S3) exhibit the least percentage share for sugarcane production (i.e., 2%). From Fig. 2, it is observed that the state Uttar Pradesh (S1) exhibits the highest percentage share for area under sugarcane cultivation (i.e., 50 %), while the least percentage share for area under sugarcane cultivation is observed in states: Haryana, Punjab, Uttarakhand, Andhra Pradesh (S3), Madhya Pradesh (i.e., 2%). From Fig. 3, it is revealed that the state Tamil Nadu exhibits the highest percentage share for sugarcane yield (i.e., 11%) as compared to the other states, whereas the least percentage share for sugarcane yield is observed in the state Bihar (i.e., 6 %).

The value of coefficient of variation (CV) for area under sugarcane cultivation is the least in the state S1 (i.e., 1.73). Moreover, the value of coefficient of variation (CV) for sugarcane yield is the least in the state S3 (i.e., 3.50). Hence, a consistent trend pattern in sugarcane area is observed in the state S1, and a consistent trend pattern in sugarcane yield is observed in the state S3. However in rest of the states, the values of CV are quite higher as compared to the previously mentioned states for area and yield of sugarcane, and hence these states exhibit inconsistent trend pattern.

The Cuddy-Della Valle instability index (I) in sugarcane production is the highest for the state S2 (i.e., 14.59) followed by the states S3 (i.e., 13.76) and S4 (i.e., 13.13), whereas the least value of instability index (I) is observed for the state S1 (i.e., 6.15). Hence, production of sugarcane in the states S2, S3 and S4 are comparatively more instable as compared to that of state S1. In a similar manner, the instability in area under sugarcane cultivation is observed to be higher in the state S2 (i.e., 14.72) followed by the states S3 (i.e., 11.27), S4 (i.e., 7.70) and the least instability is obtained in the state S1

(i.e., 1.45). Moreover, the instability in sugarcane yield is observed to be the highest in the State S4 (i.e., 7.39) and the least in the state S3 (i.e., 3.47).

The compound growth rate (CGR) in production of sugarcane is observed to be the highest in the state S1 (i.e., 4.66%). However, a declining trend in CGR for production is observed in the states S3 (i.e., -10.21%), S4 (i.e., -1.94 %), and S2 (i.e., -1.36%). In a similar manner, the CGR in sugarcane yield is observed to be positive in the state S1 (i.e., 4.34) and negative in the state S4 (i.e., -1.47), S2 (i.e., -0.23), and S3 (i.e., -0.16).

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