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Growth and instability in area, production and productivity of sugarcane in India

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Abstract

Sugarcane is an important commercial crop in India and provides a major raw material base for the sugar industry. The present study examined the growth and instability in area, production and productivity of sugarcane in India during 2004-05 to 2023-24. The study was based entirely on secondary time-series data obtained from published sources. Compound Annual Growth Rate (CAGR) was used to estimate the growth trend, while the Coefficient of Variation (CV) and Cuddy-Della Valle Instability Index (CDVI) were employed to measure instability. The average area under sugarcane cultivation was 4.838 million hectares, with average production of 354.324 million tonnes and average productivity of 73.663 tonnes per hectare. The results showed positive and statistically significant growth in area, production and productivity, with CAGR values of 0.925, 2.094 and 1.391 per cent per annum, respectively. Production registered the highest growth, followed by productivity and area. The instability analysis showed that production had the highest instability, with CV and CDVI values of 0.16 and 0.09, respectively. Area recorded CV and CDVI values of 0.10 and 0.08, while productivity recorded 0.09 and 0.04, respectively. The findings indicate that the increase in sugarcane production was associated more strongly with productivity improvement than with expansion of cultivated area. The results underline the importance of improving productivity, strengthening climate-resilient production practices and maintaining stability in sugarcane output.

Keywords: Sugarcane, area, production, productivity, growth, instability, CAGR, Cuddy-Della Valle index

Introduction

Agricultural commodities play an important role in India's economy through production, employment, processing and trade. Sugarcane is one of the important commercial crops of the country and has strong linkages with the agro-processing sector. The performance of sugarcane production is therefore important not only for farmers but also for the sugar industry and related economic activities.

India is one of the major sugarcane-producing countries in the world. Sugarcane cultivation provides raw material for sugar processing and contributes to farm income, rural employment and the wider agro-industrial economy. The performance of sugarcane production is influenced by cultivated area, productivity, irrigation, production technology, weather conditions, input management and price and policy conditions.

An assessment of growth and instability in sugarcane area, production and productivity is important for understanding the long-term performance of the crop. While expansion of cultivated area can increase output, sustained production growth also depends on improvement in productivity. At the

same time, fluctuations in production can affect the availability of sugarcane for processing and consequently influence the functioning of the sugar industry.

The present study therefore focuses specifically on the growth and instability of sugarcane area, production and productivity in India during 2004-05 to 2023-24. The objective was to quantify the long-term growth pattern and the extent of variability in these three components.

Materials and Methods

Study Area and Period of Study

The study covered the entire country of India. Secondary time-series data on sugarcane area, production and productivity were analysed for twenty years from 2004-05 to 2023-24.

Nature and Sources of Data

The study was entirely based on secondary data. Data relating to sugarcane area, production and productivity were obtained from published sources used in the thesis, including the U.S. Department of Agriculture (USDA), Directorate General of

Commercial Intelligence and Statistics (DGCIS) and other relevant organizations.

Analytical Tools

Compound Annual Growth Rate (CAGR) was used to examine the trend in sugarcane area, production and productivity. The growth equation was estimated using an exponential growth function and transformed into semi-logarithmic form. The statistical significance of the regression coefficient was tested using the Student's t-test. The compound annual growth rate was estimated using the exponential growth function assuming additive error terms as follows:

$$Y = a.b^t \quad (1)$$

Where,

Y = Depended variable for which growth rate is to be estimated (Quantity exported / export value / unit value)

a = Intercept

b = Regression Coefficient

t = Time Variable

The equation was transformed into a semi-log form as:

$$\log Y = \log a + t \log b \quad (2)$$

The percentage compound growth rate (g) was computed as:

$$\text{CAGR}(g) = (\text{antilog } b - 1) \times 100 \quad (3)$$

The statistical significance of the estimated regression coefficient was tested using the student's 't' test.

Instability Index

To study the variability in area, production, productivity of sugarcane and export quantity and export value of sugar, an instability index was used. The degree of instability was measured using the Coefficient of Variation (CV) and Cuddy–Della Valle Instability Index (CDVI).

Coefficient of Variation (CV)

Wherever the trend in the time series data was found to be non-significant, instability was analyzed using the coefficient of variation. It was calculated using the following formula:

$$CV = \frac{\sigma}{\bar{X}} \times 100$$

Where,

CV = Coefficient of variation

σ = Standard deviation

$\bar{X}$ = Arithmetic mean

$$\sigma = \sqrt{\frac{\sum(X - \bar{X})^2}{n}}$$

Where,

σ = Standard deviation

X = Variable

$\bar{X}$ = Arithmetic mean

n = Number of observations

Cuddy–Della Valle's Instability Index (CDVI)

The Cuddy–Della Valle Index was used to measure instability by adjusting the coefficient of variation for trend effects. It provides an approximation of average year-to-year percentage variation.

$$\text{Instability Index} = CV\sqrt{(1 - R^2)}$$

Where,

CV = Coefficient of variation

R^2 = Coefficient of determination

Tabulation Analysis (Descriptive Statistics)

Descriptive statistical tools such as averages and percentages were used to summarize and present the data in tabular form for meaningful interpretation and analysis.

Results and Discussion

Descriptive Statistics

The descriptive statistics in Table 1 indicated that the average area under sugarcane cultivation during the study period was 4,838 million hectares. Average production was 354.324 million tonnes, while average productivity was 73.663 tonnes per hectare. The maximum area, production and productivity were 5,890 million hectares, 465.049 million tonnes and 85.000 tonnes per hectare, respectively. The corresponding minimum values were 3,660 million hectares, 237.090 million tonnes and 64.553 tonnes per hectare. The standard deviation was 0.490 for area, 55.591 for production and 6.987 for productivity, showing comparatively greater variability in production.

Growth in Area, Production and Productivity

The estimated CAGR in Table 2 showed positive growth in all three components. Sugarcane area increased at 0.925 per cent per annum, production increased at 2.094 per cent per annum and productivity increased at 1.391 per cent per annum. All three growth rates were statistically significant at the 1 per cent level. Production recorded the highest growth, followed by productivity and area.

The higher growth rate of production compared with area indicates that improvement in productivity made an important contribution to the increase in sugarcane output. Area expanded more slowly, whereas productivity showed a stronger rate of growth. The significant t-values further confirm that the estimated growth rates represented systematic upward trends rather than random year-to-year variation.

Instability in Area, Production and Productivity

The instability analysis in Table 3 showed that sugarcane production experienced the highest variability among the three components. The CV was 0.16 for production compared with 0.10 for area and 0.09 for productivity. Similarly, the CDVI was 0.09 for production, 0.08 for area and 0.04 for productivity.

The higher instability in production indicates that sugarcane output was more susceptible to year-to-year fluctuations than cultivated area and productivity. Productivity showed the lowest instability according to both measures, suggesting comparatively greater stability in yield performance during the study period. The pattern also indicates that changes in

production were influenced not only by changes in area but also by fluctuations in productivity and other production conditions.

Table 1: Descriptive statistics of area, production and productivity of sugarcane in India

Descriptive Statistics	Area	Production	Productivity
Mean	4.838	354.324	73.663
Median	4.960	353.830	70.621
Maximum	5.890	465.049	85.000
Minimum	3.660	237.090	64.553
Std. Dev.	0.490	55.591	6.987
Skewness	-0.412	-0.119	0.530
Kurtosis	1.136	0.056	-1.333
Observations	20	20	20

Note: Area is expressed in million hectares, production in million tonnes and productivity in tonnes per hectare.

Table 2: Growth in area, production and productivity of sugarcane in India

Particulars	Area	Production	Productivity
Mean	4.838	354.324	73.663
CAGR	0.925***	2.094***	1.391***
SE	0.001	0.002	0.001
"t" Value	3.158	6.032	9.096

Note: *** indicates significance at 1 per cent. Area is in million ha, production in million tonnes and productivity in tonnes/ha.

Table 3: Instability in area, production and productivity of sugarcane in India

Particulars	Area	Production	Productivity
CV	0.10	0.16	0.09
CDVI	0.08	0.09	0.04

Conclusion

The study examined growth and instability in sugarcane area, production and productivity in India during 2004-05 to 2023-24. The results revealed positive and statistically significant growth in all three components. Area, production and productivity grew at 0.925, 2.094 and 1.391 per cent per annum, respectively. Production recorded the highest growth rate, indicating that productivity improvement contributed substantially to the increase in sugarcane output.

The instability analysis revealed that production had the highest variability, while productivity was comparatively more stable. The CV and CDVI values for production were 0.16 and 0.09, respectively, compared with 0.10 and 0.08 for area and 0.09 and 0.04 for productivity. Overall, the findings indicate sustained growth in India's sugarcane sector but also highlight the need to reduce fluctuations in output.

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