

Growth dynamics of sugarcane in Belagavi district of Karnataka, India

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Abstract: Agriculture plays a significant role in the Indian economy in terms of generating employment, food security, economic development and environmental sustainability. India being a major agricultural player, contributing over 17 per cent to GDP and employing more than 50 per cent of work force. Sugarcane, vital for the sugar industry, is a significant cash crop in India, where Karnataka plays a key role in production (70.264 mt). Belagavi district in Karnataka contributing nearly half of the state's sugarcane area (293.19 thousand ha) and production (28658.78 thousand tonne). This present study evaluates sugarcane cultivation in Belagavi district from 2000-01 to 2023-24, analyzing growth trends, instability and production changes. Dividing the study period into two phases, the first (2000-01 to 2011-12) reveals fluctuating growth rates and a significant instability, particularly in production. The second phase (2012-13 to 2023-24) shows substantial growth with lower instability and improved productivity. Growth rates during first period are found to be modest in area (0.42%) and production (3.25%) with a higher production instability index (36.95%). In contrast, the second period shows a significant growth in terms of area (5.58%) and production (7.22%) with showing a moderate instability index (16.86%). Decomposition analysis indicates that area effects (79.97%) predominantly drove production changes in the first period, while yield effects (70.01%) shows improvements, this became the primary driver in the second period. Overall period, the study finds a significant growth driven by yield (113.25%) improvements, with recommendations for adopting high-yielding and drought-resistant sugarcane varieties to enhance stability and productivity, thereby supporting a more stable and productive sugarcane sector in Belagavi district.

Keywords: Compound annual growth rate, Decomposition, Instability, Sugarcane, Varieties

Introduction

Agriculture is the backbone of human civilization and plays a vital role in ensuring employment, food security, promoting economic development, environmental sustainability, preserving cultural heritage and driving scientific and technological progress. India has a highly diverse agro-climatic conditions with a wide range of crops adaptability such as rice, wheat, cotton, sugarcane, fruits, vegetables, spices and plantation crops (Adhale *et al.*, 2019). Agriculture provides employment to over 50 per cent of the population and accounting for around 17 per cent of the country's GDP (Singh *et al.*, 2021). Agriculture has been the source of raw materials to a number of key agro-industries in India such as cotton, jute, plantations, textiles, sugar, vanaspati and oils (Hanji *et al.*, 2024). In addition to these, many other industries indirectly depend on agriculture for their raw materials *e.g.*, the sugar industry is among the chief industries in India drawing its raw material from agriculture. Sugar is derived from sugarcane which is an agricultural produce (Singh *et al.*, 2010).

The total area under sugarcane cultivation in the world was about 269 lakh ha with production of 1950mt and nearly 74 tonne ha⁻¹ of productivity (Hanji *et al.*, 2024). In India, sugarcane cultivated over an area of 60.61 lakh ha, 550mt of production and 84 tonne ha⁻¹ of sugarcane productivity has acquired second position globally after Brazil which has about 87 lakh ha of area under sugarcane with an impressive production of 705mt and 79 tonne ha⁻¹ of productivity (Maurya *et al.*, 2020). The other important sugarcane producing countries in the world are Thailand, Mainland China, Pakistan, Colombia,

Philippines and USA. These countries contribute more than 80 per cent of the total area and production of sugarcane, globally. The top sugarcane cultivating states in India are Uttar Pradesh, Karnataka, Maharashtra, Bihar, Tamil Nadu, Gujarat, Madhya Pradesh and Haryana. With an area of 29.66 lakh ha and production of 2348lakh tonne of sugarcane, Uttar Pradesh occupies first position in the country, contributing nearly 48 per cent share in country's total sugarcane area and production followed by Maharashtra with area of 14.87 lakh ha and 1413 lakh tonne of sugarcane production (Adhale *et al.*, 2019). Among the major sugarcane cultivating states of India, Tamil Nadu state stands first for sugarcane productivity (107.62 tonne ha⁻¹) followed by Karnataka (93tonne ha⁻¹), Maharashtra (89 tonne ha⁻¹) and Uttar Pradesh (86 tonne ha⁻¹) (Maurya *et al.*, 2020).

Within India, the Karnataka state plays a significant role in sugarcane cultivation, underscoring its importance in the agricultural landscape of the country. The state covers over an area of 6.29 lakhha under sugarcane cultivation, which constitutes 11.15 per cent of the total area dedicated to sugarcane farming in India (Hanji *et al.*, 2024). This highlights Karnataka's substantial contribution to the nation's sugarcane industry, wherein it plays a key role among the states involved in sugarcane production.

Sugarcane cultivation in Karnataka's with an impressive production of 70.264 mt, contributing for 15.74 per cent of India's total sugarcane production, further emphasizing the state's vital role in supporting the sugarcane supply chain within the country (Hanji *et al.*, 2024). The state's favourable climate, soil

conditions and agricultural practices contribute to its high yield and productivity in sugarcane farming.

Drilling down to the district level, Belagavi district emerged as a significant contributor to Karnataka’s sugarcane industry. The district alone accounts for 46.61 per cent of the total area under sugarcane cultivation in Karnataka, covering 293.19 thousand ha (Anon, 2024). This largest share indicates the district’s central role in the state’s agricultural activities, particularly in sugarcane farming (Wali *et al.*, 2019).

In terms of production, Belagavi’s contribution is equally noteworthy. The district produces 28.659 mt of sugarcane, which constitutes 40.79 per cent of the state’s total sugarcane production (Anon, 2024). Belagavi district is considered as one of the most productive districts in Karnataka’s sugarcane cultivation, playing a critical role in the state’s overall agricultural production and the broader economic landscape.

The figures under score the strategic importance of Belagavi district within Karnataka’s sugarcane industry, reflecting the district’s advanced agricultural practices, infrastructure and focus on sugarcane as a key cash crop (Wali *et al.*, 2019). The district’s high productivity also contributes significantly to the state’s reputation as a major sugarcane producer in India, supporting both domestic and international markets (Hanji *et al.*, 2024).

Sugarcane occupies an important place among the various cash crops grown in Belagavi district. Belagavi district sugar market is the largest in Karnataka and meets the domestic sugar requirements of the state. The major byproduct of sugarcane is sugar which is largely in demand. Therefore, the study was carried out to know the growth performance of sugarcane in Belagavi district with the following objectives-

1. To analyse the growth and instability of area, production and productivity of sugarcane in Belagavi district
2. To estimate the decomposition analysis of sugarcane production in Belagavi district.

Material and methods

The study was entirely based on secondary data pertaining to the area, production and productivity of sugarcane gathered from the publications of the website of *Indiastat* and Directorate of Economics and Statistics for two decades (24 years) period from 2000-01 to 2023-24. The entire study period was divided into two periods as Period I (2000-01 to 2011-12) and Period-II (2012-13 to 2023-24) to analyse the growth performance of sugarcane production in Belagavi district. The collected data were processed and analyzed using growth rates, instability index and decomposition analysis as detailed below.

Growth rate analysis

The compound annual growth rate (CAGR) is a useful measure of growth over multiple time periods. In the present study, the CAGR was used to analyze the growth trends in area, productivity and production of sugarcane in Belagavi district of Karnataka State. The compound growth rates were worked out for a period of twenty-four years covering from

2000-01 to 2023-24. The CAGR was estimated by fitting a semi-log trend equation model of the following form for various parameters of sugarcane mentioned below:

$$Y_t = AB^t u_t \dots\dots\dots (1)$$

Where,

Y_t = Area/Production/Productivity of sugarcane during time t

A = Constant / intercept indicating Y in the base period (t=0)

t = Time period

u_t = Error term

B = (1+g)

Where,

g = growth rate

The above equation (1) would become linear by taking the logarithm on both the sides of the model.

$$\ln Y_t = \ln A + t (\ln B) + \ln u_t \dots\dots\dots (2)$$

Where,

ln A and ln B are the parameters of the function obtained by Ordinary Least Square (OLS) method. Then growth rate ‘g’ was computed as follows:

$$g = [\text{Antilog}(B) - 1] \times 100 \dots\dots\dots (3)$$

Where,

g = Compound annual growth rate

B = Regression coefficient

Instability analysis

Stability is the quality or characteristic of being stable and lack of stability indicate the situation of instability. The value of any parameter which is not likely to move or change is termed as stable. For example, instability in prices can be defined as the state, in which prices of a commodity subject to change with time in a market. The extent of instability thus, needs to be examined in relation to time and was attempted with respect to area, productivity and production of sugarcane.

Instability analysis represents the uncertainty with the help of indicators like Coefficient of Variation, Standard Deviation, various Instability Indices, *etc.* In the present study instability in area, production and productivity of sugarcane was analyzed using the Cuddy Della Valle Index (CDVI).

Cuddy della valle index (CDVI)

The instability in area, production and productivity of sugarcane was analysed using Cuddy-Della Valle Index with modified coefficient of variation (CV) formula as given below (Cuddyand Valle, 1978).

$$\text{Coefficient of Variation (CV)} = (S.D/\text{Mean}) * 100 \dots\dots\dots (4)$$

$$\text{CDVI} = \text{CV} * \sqrt{1 - \text{adjusted } R^2} \dots\dots\dots (5)$$

Where,

S. D. = Standard deviation

R^2 = Coefficient of multiple determination

The extent of instability was categorized into three levels based on the value of CDVI *i.e.*,

Low instability = 0-15 per cent, Moderate instability = 15-30 per cent, High instability = >30 per cent.

Decomposition analysis

To measure the relative contribution of area, yield to the total production of the sugarcane crop (Minhas and Vaidyanath, 1965), Decomposition analysis model was used which is given below:

$$P_o = A_o \times Y_o \text{ and}$$

$$P_n = A_n \times Y_n \dots\dots\dots (6)$$

A_o, P_o and Y_o are area, production and productivity in base year and A_n, P_n and Y_n are values of the respective variable in nth year item respectively.

Where,

A_o and A_n = Area

Y_o and Y_n = yield in the base year and nth year respectively.

$$P_n - P_o = \Delta P$$

$$A_n - A_o = \Delta A$$

$$Y_n - Y_o = \Delta Y \dots\dots\dots (7)$$

For equation (6) and (7) we can write P_o + ΔP = (A_o + ΔA) (Y_o + ΔY)

Hence,

$$P = A_o \Delta Y / \Delta P * 100 + Y_o \Delta A / \Delta P * 100 + \Delta Y \Delta A / \Delta P * 100$$

(Production = Yield effect + area effect + interaction effect)

Thus, the total change in production can be decomposed into yield effect, area effect and the interaction effect due to change in yield and area.

Results and discussion

We can observe in Table 1 that India contributed significantly to global sugarcane production from 2023-24 season with area under sugarcane cultivation (5,642 thousand ha) accounting for 21.7 per cent of the world’s sugarcane area while production was 4,46,430 thousand tonnes, representing 23.25 per cent of global sugarcane production. Within India, Karnataka plays a significant role which covered an area under sugarcane (629 thousand ha) with 11.15 per cent share of the country’s area and production was 70,264 thousand tonnes which accounted 15.74 per cent of India’s total sugarcane production. Notably, the Belagavi district in Karnataka was a major contributor, with 46.61 per cent of the state’s sugarcane area (293.19 thousand ha) and production was 40.79 per cent of Karnataka’s total sugarcane production (28,658.78 thousand tonnes).

Table 1. Share of area and production of sugarcane (2023-24).

Particular	Area (₹ 000 ha)	Share (%)	Production (₹ 000 tonne)	Share (%)
India contribution in Globe	5642.00	21.70	446430.00	23.25
Karnataka contribution in India	629.00	11.15	70264.00	15.74
Belagavi district contribution in Karnataka	293.19	46.61	28658.78	40.79

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Govt. of India.

Table 2. Performance of area, production and productivity of sugarcane in Belagavi district during Period-I

Year	Area (ha)	Production (tonne)	Productivity (tonne/ ha)
2000-2001	174706	17924836	102.60
2001-2002	156043	10969823	70.30
2002-2003	145133	10892232	75.05
2003-2004	105237	4898782	46.55
2004-2005	135471	8920279	63.97
2005-2006	92971	8213988	88.35
2006-2007	97762	8265777	84.55
2007-2008	102845	9281761	90.25
2008-2009	114181	9654004	84.55
2009-2010	147298	14972842	101.65
2010-2011	187884	18027470	95.95
2011-2012	171205	16264475	95.00
Average	135894.67	11523855.75	83.23
CAGR (%)	0.42 ^{NS}	3.25 ^{NS}	2.85 ^{NS}
CDVI (%)	25.31	36.95	18.77

Note: ***Significant at 1 per cent level; **Significant at 5 per cent level; *Significant at 10 per cent level; ^{NS} Non-Significant

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Govt. of India

The result depicted in Table 2 during Period-I, the sugarcane cultivation area in Belagavi district showed fluctuating trends, with the area ranging from 92,971 ha in 2005-06 to a highest of 187,884 ha in 2010-11 with an average area increased by a two fold (135,894.67 ha) over a period of five years. Sugarcane production observed was lowest in 2003-04 (4.89 mt) and it was a highest in 2010-11(18.03 mt) with production increased by more than three times (11.52 mt) (Wali *et al.*, 2019). Productivity significantly varied from a lowest in 2003-04 (46.55 tonnes ha⁻¹) and highest in 2000-01(102.60 tonnes ha⁻¹) with productivity enhanced by more than double (83.23 tonnes ha⁻¹). Sugarcane production in Belagavi district showed a non-significant compound growth rate was highest (3.25%) followed by productivity (2.85%) and area (0.42%), indicating a lack of consistent growth in area under sugarcane. The Instability index (CDVI) reflected a highest variability (36.95%) in sugarcane production as compared to productivity (18.77%) and area under cane cultivation exhibiting medium level of instability (25.31%). These figures suggest that, similar results of the overall trends in sugarcane cultivation in the present study period were marked by significant variability and instability observed in the findings of Anjum (2018).

The result observed in Table 3 during Period-II, the sugarcane cultivation area in Belagavi district showed a substantial increase from 168,128 ha in 2012-13 to 293,195 ha in 2023-24 with an average area of 209,427 ha and it was increased by 1.74 times during the study period. Sugarcane production showed a similar upward trend, rising from 2012-13 (13.90 mt) to 2023-24 (28.66 mt) with average sugarcane production of 19.09 mt and it was enhanced by two-fold times. Cane productivity also observed to be increasing trend, with values ranging from 2016-17 (65.55 tonnes ha⁻¹) to 2020-21 (101.00 tonnes ha⁻¹) with the average productivity of 91.00 tonnes ha⁻¹ and it was increased by 1.54 times. Sugarcane production in Belagavi district showed a significant positive compound growth rate of

Table 3. Performance of area, production and productivity of sugarcane in Belagavi district during Period-II

Year	Area (ha)	Production (tonne)	Productivity (tonne/ ha)
2012-2013	168128	13895779	82.65
2013-2014	159443	14389731	90.25
2014-2015	180571	16296533	90.25
2015-2016	175778	14528052	82.65
2016-2017	163511	10718146	65.55
2017-2018	208729	20622425	98.80
2018-2019	206864	19062518	92.15
2019-2020	189896	17732573	93.38
2020-2021	205559	20346248	101.00
2021-2022	277275	26086055	96.00
2022-2023	284170	26734714	96.00
2023-2024	293195	28658780	98.00
Average	209427.00	19089296.00	91.00
CAGR (%)	5.58***	7.22***	1.71 ^{NS}
CDVI (%)	10.76	16.86	9.70

Note: ***Significant at 1 per cent level; **Significant at 5 per cent level; *Significant at 10 per cent level; ^{NS} Non-Significant

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Govt. of India.

7.22 per cent per annum over the study period (2012-13 to 203-24) with representing medium level of instability (16.86 %). An increase in production was mainly due to increased area under sugarcane. The area under sugarcane increased at the growth rate of 5.58 per cent per annum with exhibiting a lower level of instability (10.76%). While, the growth rate for sugarcane productivity was non-significant as revealed by lowest positive growth rate (1.71%). This was also supported by very low level of instability (9.70%) indicating more or less stagnated yield levels (Table 3).

The high positive growth rates in area and production may be attributed by the availability of high-yielding varieties, irrigation facilities, production technology, farm mechanization, coupled with favourable climatic conditions and better access to the nearby sugar factories. Further, farmers will be under impression of high profitable nature of sugarcane, as they receive large lumpsum amount as payment for their cane supplied to factories, even though the returns per rupee of investment for sugarcane is lower than many of the other seasonal agricultural crops, vegetables, flowers and other horticultural crops. In addition, farmers need to be addressed with the current excess situation of sugar production in the country and inability to find suitable foreign markets for exports and adversely affecting the domestic (low) prices and

Table 4. Performance of area, production and productivity of sugarcane in Belagavi district during overall Period (2000-2024).

	Area (ha)	Production (tonne)	Productivity (tonne/ ha)
Average	172660.62	15306575.96	86.89
CAGR (%)	3.53***	4.68***	1.19 ^{NS}
CDVI (%)	20.96	27.63	14.53

Note: ***Significant at 1 per cent level; **Significant at 5 per cent level; *Significant at 10 per cent level; ^{NS} Non-Significant

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Govt. of India.

compelling factories for irregular payments and assure fair and remunerative prices as observed by Hanji *et al.* (2024).

Average area under sugarcane cultivation in Belagavi district was 172,660.62 ha with an average production of 15.31 mt and productivity of 86.89 tonnes ha⁻¹ are presented in Table 4 during overall study period (2000-01 and 2023-24). The compound annual growth rate was showing significant for both area (3.53 %) and production of sugarcane (4.68%) which signifying modest growth, while cane productivity registered a non-significant growth rate of 1.19 per cent per annum and the more or less similar trends were observed by Adhale *et al.*, (2019) in their study. The instability index (CDVI) was observed to be highest in case of sugarcane production (27.63%) followed by area (20.96%) and productivity (14.53%). The growth trends in area, production and productivity of sugarcane in Belagavi district of Karnataka state over the study period is also graphically presented in Fig. 1. A polynomial trendline with an R² value of 74 per cent further emphasizes the considerable but fluctuating growth trends in Belagavi district sugarcane sector, indicating significant expansion in both area and production, even as yield improvements remained statistically non-significant and the same trend as observed by Hanji *et al.*, (2024).

The results shown in Table 5 depicts that decomposition analysis of sugarcane production in Belagavi district reveals distinct trends observed across different study periods. During Period I, the primary driver of change in sugarcane production was area effect (79.97%), while the yield effect contributed 21.63 per cent. The interaction effect was found to be negative (-1.60%) indicating a slight reduction in cane production, this might be due to combined effects of changes in area and yield as observed by Anjum, (2018). In Period II, the yield effect became the dominant factor with a substantial contribution of 70.01 per cent results in change in sugarcane production but the area effect contributing a smaller share to the tune of 17.48 per cent and the interaction effect contributing positively with a lower share of 13.00 per cent. During overall study period

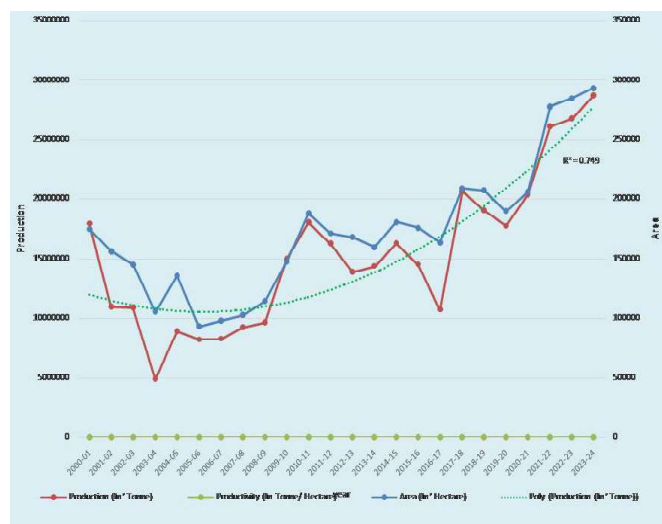


Fig 1. Trends in area, production and productivity of sugarcane in Belagavi district during overall study period (2000-2024)

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Table 5. Contribution of area, yield and their interaction for change in production of sugarcane in Belagavi district.

DECOMPOSITION ANALYSIS (%)			
Period	Yield Effect	Area Effect	Interaction Effect
Period I	21.63	79.97	-1.60
Period II	70.01	17.48	13.00
Overall	113.25	-7.48	-5.07

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Govt. of India.

from 2000-01 to 2023-24, the cane yield effect showing significantly influenced production with a highest contribution of 113.25 per cent change while the area effect (-7.48%) and interaction effect (-5.07%) were found to be negative. This indicates that overall sugarcane production increases were primarily driven by improvements in cane yield levels, while changes in sugarcane area had a minimal or slightly negative impact and the similar results were observed by Maurya *et al.*, (2020).

From Table 1, 2, 3, during 2000-01 and 2023-24, sugarcane cultivation in Belagavi district showed fluctuating trends. In the first period, the average area under sugarcane was about 135,895 ha, with average production of 11.52 mt and productivity of 83.23 tonnes ha⁻¹. The growth rates were observed to be lowest in terms of area (0.42 %) and production (3.25 %) with exhibiting a higher level of instability in sugarcane production (36.95%). The second period saw a significant growth trends with an average area under sugarcane was 209,427 ha and production (19.09 mt) with a productivity (91.00 tonnes ha⁻¹). The CAGR increased to 5.58 per cent per annum for area and

7.22 per cent per annum for production of sugarcane. During overall study period, cane production growth was largely driven by yield improvements (113.25%) while the area effect was negative (-7.48%). Decomposition analysis confirmed that sugarcane yield was the primary contributor to change in sugarcane production as observed by Maurya *et al.*,(2020).

Conclusion

The study concludes that sugarcane cultivation in Belagavi district has experienced prominent growth trends over the study periods. While the area under sugarcane cultivation saw considerable growth, it was marked by variability and fluctuating growth rates. Sugarcane production levels also demonstrated significant growth, particularly during study Period II, driven mainly by improvements in cane yield levels. Despite overall positive trends in sugarcane, there were significant fluctuations observed, especially in cane production, indicating some instability. The decomposition analysis revealed that yield improvements were the primary driver of increased cane production, while changes in area had a minimal or slightly negative impact. To enhance stability and boost sugarcane production, as it is recommended that high-yielding and drought-resistant sugarcane varieties to be adopted by the farmers. This approach would mitigate risks for sugarcane growers, increase cultivation areas and ultimately contribute to a more stable observed in productive sugarcane sector in Belagavi district. The present study would be more focused on growth and instability in area, production and productivity of sugarcane leaving scope for future economic studies on sugarcane market and price aspects which may help the growers to realize better income.

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