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Trends in Area, Production and Productivity of Sugarcane in India, Maharashtra and Kolhapur District

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Abstract

Sugarcane is one of the most important commercial crops of India, occupying only about 2.5 per cent of the gross cropped area but contributing nearly 1.1 per cent to the national GDP and supporting the livelihood of more than five crore farmers. India ranks second in the world in area and production of sugarcane after Brazil, and records the highest productivity among the major producing countries. Within India, Maharashtra is a leading sugarcane-producing state on account of its favourable agro-climatic conditions and strong cooperative sugar sector, and Kolhapur district occupies a prominent position within the state owing to assured irrigation and fertile soils. The present study examines the trends in area, production and productivity of sugarcane at the national, state and district levels - India and Maharashtra (2005-06 to 2024-25) and Kolhapur district (2003-04 to 2022-23) - using secondary time-series data compiled from the Ministry of Agriculture and Farmers Welfare, Government of India, and the Department of Economics and Statistics. Compound annual growth rate (CAGR) and coefficient of variation (CV) were used to measure growth and instability, respectively. Area, production and productivity grew at 0.88, 2.22 and 1.33 per cent per annum at the national level, 2.57, 3.29 and 0.70 per cent per annum in Maharashtra, and 3.54, 4.85 and 1.26 per cent per annum in Kolhapur district, all statistically positive significant, with growth rates rising consistently from the national to the district level. Area and production were considerably more unstable than productivity at every level, reflecting the continuing influence of monsoon variability and sugarcane-pricing policy on farmers' cultivation decisions.

Keywords: Compound annual growth rate, Coefficient of variation, Productivity, Sugarcane, Trends

1. Introduction

Sugarcane (*Saccharum officinarum* L.) is the principal source of sweeteners in India and one of the country's most important commercial crops, forming the raw material base for the sugar, jaggery and ethanol industries. Although it is cultivated on only about 2.5 per cent of the gross cropped area of the country, it contributes nearly 1.1 per cent to the national GDP, reflecting its high value per unit area relative to most other field crops. The crop and its allied industries support the livelihood of more than five crore farmers and provide direct and indirect employment to millions of agricultural and industrial workers, making sugarcane cultivation central to rural industrialisation and socio-economic development in the producing regions. India is also the world's largest producer of jaggery, accounting for a substantial share of global output, with a sizeable proportion of the country's sugarcane crop diverted each year towards jaggery and khandsari manufacturing.

India ranks second in the world in both area and production of sugarcane, after Brazil, and records the highest productivity among the major sugarcane-producing countries, reflecting the widespread adoption of improved varieties and better crop-management practices. Within the country, sugarcane is grown under two broad agro-climatic regions, tropical and sub-tropical, and its cultivation is spread across several states, of which Uttar Pradesh leads in terms of area while Maharashtra, aided by favourable agro-climatic conditions and a strong cooperative

sugar sector, records the highest sugarcane productivity among the major producing states. Within Maharashtra, Kolhapur district occupies a prominent position on account of its assured irrigation network along the Panchganga and Krishna river basins, fertile alluvial and black soils, and a dense network of cooperative and private sugar factories, all of which make sugarcane integral to the livelihood of rural households in the district.

Despite its economic importance, the area, production and productivity of sugarcane in India have not followed a uniform or steady trend; the crop has instead shown a persistently fluctuating pattern of growth. This is attributable to a combination of factors, including unpredictable monsoon conditions, water scarcity, government sugarcane-pricing policy, delays in payment by sugar mills and the generally low level of mechanisation among small and marginal sugarcane farmers. Because these constraints operate with different intensity at the national, state and district level, an examination of sugarcane performance confined to a single spatial level can mask important local variation. A comparative assessment of trends across the country, the state and a leading producing district is therefore useful in identifying whether growth in sugarcane output is being driven mainly by expansion of area or by genuine improvement in yield, and whether instability in cultivation is more pronounced at higher or lower levels of aggregation.

Against this background, the present study was undertaken with the specific objectives of (i) examining the trend in area, production and productivity of sugarcane in India, Maharashtra and Kolhapur district over the available reference periods, and (ii) comparing the compound annual growth rates and the degree of instability in area, production and productivity across these three spatial levels.

2. Methodology

The study is based entirely on secondary data. Time-series data on area, production and productivity of sugarcane for India and for Maharashtra state, covering the period 2005-06 to 2024-25, were compiled from published reports of the Ministry of Agriculture and Farmers Welfare, Government of India. Corresponding data for Kolhapur district, covering the period 2003-04 to 2022-23, were compiled from the Department of Economics and Statistics (E and S), DAC, New Delhi. Kolhapur district was purposively selected for the district-level analysis in view of its high sugarcane area, production and recovery rate within Maharashtra.

2.1 Statistical Analysis of Data.

A) Percentage change in area, production and productivity of Sugarcane

The year-to-year percentage change in area, production and productivity was worked out as:

$$\% \text{ change} = \frac{[(\text{Current year value} - \text{Previous year value}) / \text{Previous year value}] \times 100}{}$$

B) Compound Annual Growth Rates

$$Y = ab^t$$

where,

Y= Dependent variable

a= Intercept,

b = Regression co-efficient,

t = Time variable.

The compound annual growth rates (CAGR) were obtained by using the logarithmic form of the equation.

$$\text{Log } Y = \text{Log } a + t \text{ Log } b$$

The compound growth rate (CAGR) in per cent = Antilog $(b-1) \times 100$

The compound growth rates were tested for their significance by using Student's 't' test.

$$t = \frac{b}{SE}$$

C) Coefficient of Variability

The coefficient of variation around the mean was utilised to measure instability in the area, production and productivity of sugarcane. The Coefficient of Variation (CV) was calculated by using the formula,

$$CV (\text{per cent}) = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

The Coefficient of Variation (CV) classification outlined by Harka *et al.* (2021) [7] is:

- CV is less than 20: less variation
- CV is between 20 to 30: moderate variation
- CV is greater than 30: high variation
- CV is greater than 50: very high variation

3. Results and Discussion

3.1 Trends in Area, Production and Productivity of Sugarcane in India

Table 1 presents the trend in area, production and productivity of sugarcane in India over the twenty-year period 2005-06 to 2024-25. The area under sugarcane cultivation increased from 4,202.00 thousand hectares in 2005-06 to 5,449.93 thousand hectares in 2024-25, registering an overall increase of about 29.70 per cent, though the year-to-year movement was distinctly fluctuating rather than steady. Area recorded a sharp jump of 22.58 per cent in 2006-07, followed by successive contractions during 2007-08 to 2009-10 and again a fall of 9.97 per cent in 2016-17, before recovering to a peak of 5,885.32 thousand hectares in 2022-23 and then declining again in the last two years of the series.

Production followed a broadly similar but steeper trajectory, rising from 281,172.00 thousand tonnes in 2005-06 to 454,610.97 thousand tonnes in 2024-25, an overall increase of about 61.68 per cent. Production growth outpaced area growth in most years, most visibly in 2006-07 (26.44%), 2017-18 (24.12%) and 2020-21 (9.42%), indicating that yield gains rather than area expansion alone were driving output in these years. Productivity improved from 66.91 tonnes per hectare in 2005-06 to 83.42 tonnes per hectare in 2024-25, an increase of about 24.67 per cent, but the improvement was uneven, with a notable dip in 2008-09 (-6.24%) and 2018-19, and a sharp rise of 16.23 per cent in 2017-18 that lifted productivity above 80 tonnes per hectare for the first time in the series and kept it there for most subsequent years. Since the growth in production consistently exceeded the growth in productivity over the period, the expansion of national sugarcane output has been driven jointly by area expansion and yield improvement, with area playing the comparatively larger role, a pattern consistent with the area-led national growth reported by Bee and Rahman (2020) [4] for the earlier period 1985-2015 and by Singh *et al.* (2022) [10].

The decline recorded in the last two years of the series, area falling by 2.48 per cent in 2023-24 and a further 5.05 per cent in 2024-25, and production falling by 7.62 per cent in 2023-

24, is largely explained by weather-related and crop-health factors that affected the major producing states together. Below-average rainfall during 2023 lowered reservoir levels across Maharashtra and Karnataka, subjecting the standing sugarcane crop to prolonged water stress, while the subsequent 2024 monsoon brought excessive and unevenly distributed rainfall with limited sunshine that further stunted crop growth and reduced sugarcane yield by an estimated 10 to 15 tonnes per hectare in the worst-affected tracts. In Uttar Pradesh, the country's largest sugarcane-growing state, output was additionally depressed by red-rot infestation in the widely

planted CO 0238 variety, which forced farmers into premature uprooting, crop rotation and replanting. A part of the reduced sugarcane availability for sugar production in these years also reflects diversion of standing sugarcane towards seed for fresh planting after the 2023-24 drought and towards ethanol manufacture under the government's ethanol-blending programme, rather than an equivalent fall in the crop actually grown. Together, these climatic, disease and diversion-related factors account for the simultaneous decline in both area and production observed nationally in the most recent years of the series.

Table 1: Area, Production and Productivity of Sugarcane in India (2005-06 to 2024-25)

Year	Area ('000 ha)	% change	Production ('000 Tonnes)	% change	Productivity (Tonnes/ha.)	% change
2005-06	4202.00	-	281172.00	-	66.91	-
2006-07	5151.00	22.58	355520.00	26.44	69.00	3.12
2007-08	5055.00	-1.86	348188.00	-2.06	68.90	-0.14
2008-09	4415.00	-12.66	285026.00	-18.14	64.60	-6.24
2009-10	4175.00	-5.44	292300.00	2.55	70.00	8.36
2010-11	4885.00	17.01	342382.00	17.13	70.10	0.14
2011-12	5038.00	3.13	361037.00	5.45	71.70	2.28
2012-13	4999.00	-0.77	341200.00	-5.49	68.30	-4.74
2013-14	4993.00	-0.12	352142.00	3.21	70.50	3.22
2014-15	5067.00	1.48	362333.00	2.89	71.50	1.42
2015-16	4927.00	-2.76	348448.00	-3.83	70.70	-1.12
2016-17	4436.00	-9.97	306069.00	-12.16	69.00	-2.40
2017-18	4737.00	6.79	379905.00	24.12	80.20	16.23
2018-19	5061.00	6.84	405416.00	6.72	80.10	-0.12
2019-20	4602.68	-9.06	370500.30	-8.61	80.50	0.50
2020-21	4851.23	5.40	405398.71	9.42	83.57	3.81
2021-22	5175.41	6.68	439424.89	8.39	84.91	1.60
2022-23	5885.32	13.72	490533.35	11.63	83.35	-1.84
2023-24	5739.60	-2.48	453158.49	-7.62	78.95	-5.28
2024-25	5449.93	-5.05	454610.97	0.32	83.42	5.66

Source: Ministry of Agriculture and Farmers Welfare, Government of India

3.2 Trends in Area, Production and Productivity of Sugarcane in Maharashtra

Table 2 shows that sugarcane area in Maharashtra expanded from 501.00 thousand hectares in 2005-06 to 1,167.00 thousand hectares in 2024-25, an overall increase of about 132.93 per cent, considerably higher in relative terms than the increase recorded for India as a whole. The state's area series was, however, markedly volatile: area more than doubled in a single year in 2006-07 (109.38%), fell by nearly 30 per cent in 2008-09 and again in 2019-20 (-29.27%), and swung by double digits in most other years, reflecting the sensitivity of area allocation to sugarcane price incentives, water availability and competition from other crops.

Production rose from 38,853.00 thousand tonnes to 109,970.00 thousand tonnes over the same period, an overall increase of about 183.04 per cent, a rate of increase substantially higher than that of area, which points to a meaningful yield contribution alongside area expansion. Productivity improved only modestly in relative terms, from 77.55 to 94.23 tonnes per hectare (about 21.51% overall), and this improvement was far from uniform, including a fall of 16.09 per cent in 2018-19 followed by a rise of 20.81 per cent in 2024-25. Taken together, these figures indicate that, in line with the findings of Deokate (2013) ^[5] and Adhale *et al.* (2019) ^[1], sugarcane output growth in Maharashtra over the study period was driven predominantly by area expansion,

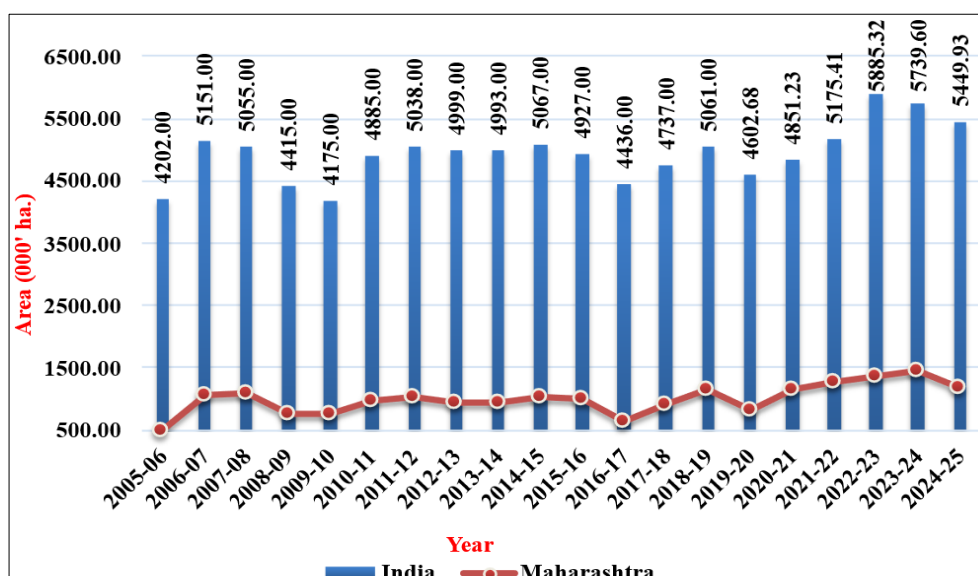
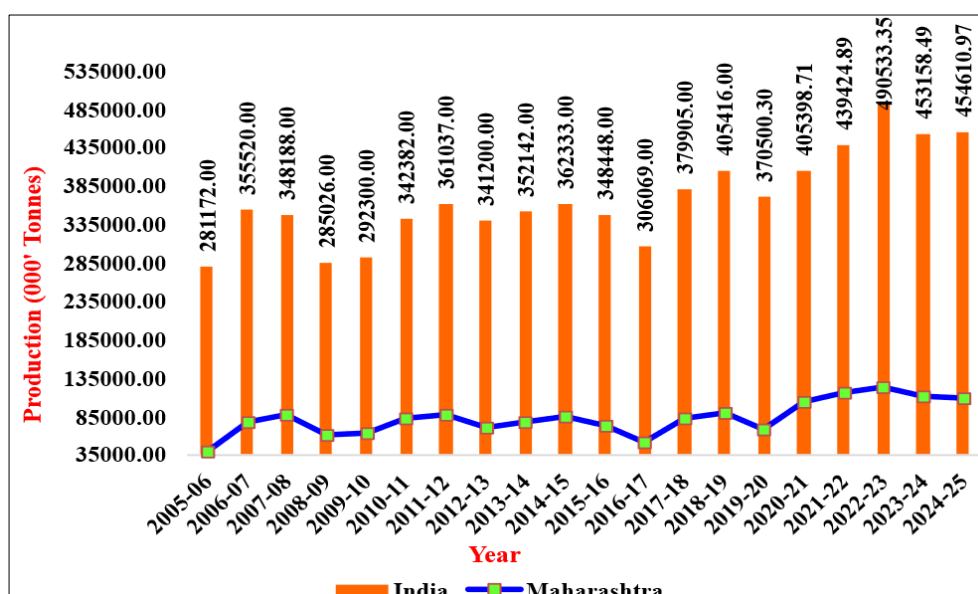
with productivity contributing a comparatively smaller and more erratic share.

The sharp fall in production of 9.58 and 1.89 per cent in 2023-24 and 2024-25, respectively, and in area of 18.79 per cent in 2024-25, was driven by a combination of factors specific to the state in these years. The 2023 monsoon was deficient over large parts of Maharashtra, lowering reservoir storage and forcing farmers to divert part of the standing crop towards planting material (Sugarcane setts) for the following season instead of sending it for crushing, which reduced both the effective area harvested and the sugarcane actually crushed in 2024-25. Insufficient and unevenly distributed rainfall during the 2024 growing season further affected sugarcane quality and growth. Crushing operations were also delayed because the state government postponed the start of the season to mid-November 2024 on account of the state assembly elections, shortening the effective crushing period, while several border districts lost sugarcane to Karnataka's sugar factories, which commenced crushing roughly a fortnight earlier. In addition, a policy shift permitting greater use of sugarcane juice and B-heavy molasses for ethanol production redirected a part of the sugarcane crop away from sugar manufacture. Consequently, mills in Maharashtra crushed nearly 19 per cent less sugarcane and produced about 24 per cent less sugar in 2024-25 than in 2023-24, mirroring the fall recorded in the area and production series.

Table 2: Area, Production and Productivity of Sugarcane in Maharashtra (2005-06 to 2024-25)

Year	Area ('000 ha)	% change	Production ('000 Tonnes)	% change	Productivity (Tonnes/ha)	% change
2005-06	501.00	-	38853.00	-	77.55	-
2006-07	1049.00	109.38	78568.00	102.22	74.90	-3.42
2007-08	1093.00	4.19	88437.00	12.56	80.91	8.03
2008-09	768.00	-29.73	60648.00	-31.42	78.97	-2.40
2009-10	756.00	-1.56	64159.00	5.79	84.87	7.47
2010-11	965.00	27.65	81895.70	27.64	84.87	0.00
2011-12	1022.00	5.91	86733.10	5.91	84.87	0.00
2012-13	933.00	-8.71	69648.10	-19.70	74.65	-12.04
2013-14	937.00	0.43	76901.00	10.41	82.07	9.94
2014-15	1030.00	9.93	84699.00	10.14	82.23	0.19
2015-16	987.00	-4.17	73679.60	-13.01	74.65	-9.22
2016-17	633.30	-35.84	52262.45	-29.07	82.52	10.55
2017-18	902.00	42.43	82984.00	58.78	92.00	11.48
2018-19	1162.80	28.91	89768.16	8.18	77.20	-16.09
2019-20	822.40	-29.27	69311.87	-22.79	84.28	9.17
2020-21	1142.80	38.96	105137.60	51.69	92.00	9.16
2021-22	1261.70	10.40	116076.40	10.40	92.00	0.00
2022-23	1359.00	7.71	123968.00	6.80	91.20	-0.87
2023-24	1437.02	5.74	112087.56	-9.58	78.00	-14.47
2024-25	1167.00	-18.79	109970.00	-1.89	94.23	20.81

Source: Ministry of Agriculture and Farmers Welfare, Government of India.

**Fig 1:** Trends in Area of Sugarcane in India and Maharashtra**Fig 2:** Trends in Production of Sugarcane in India and Maharashtra

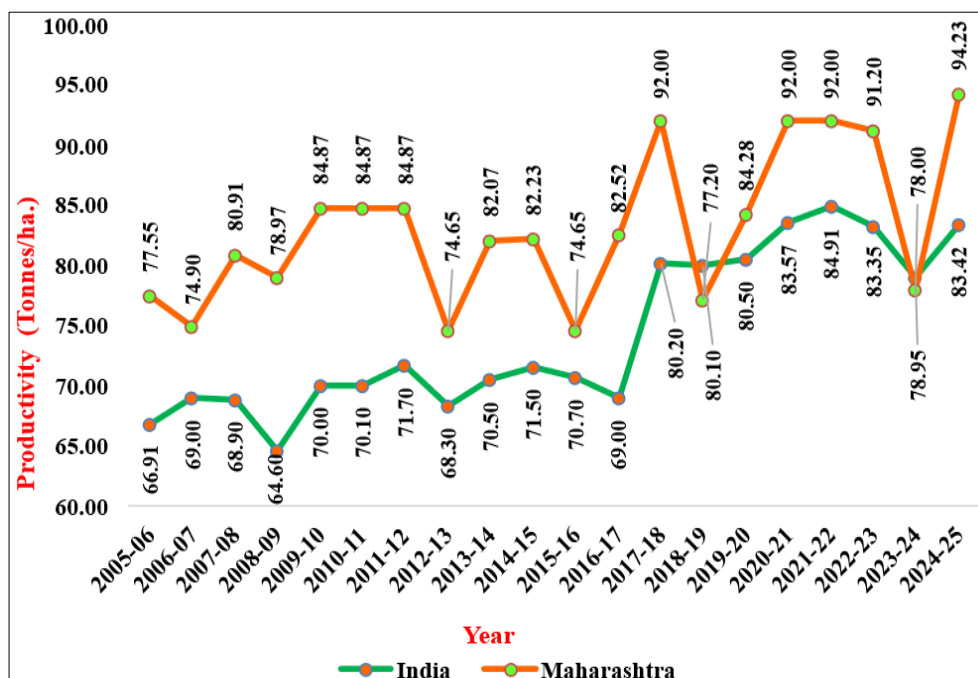


Fig 3: Trends in Productivity of Sugarcane in India and Maharashtra

3.3 Trends in Area, Production and Productivity of Sugarcane in Kolhapur District

Table 3 presents the trend for Kolhapur district over 2003-04 to 2022-23. Area under sugarcane increased from 87.00 thousand hectares to 176.00 thousand hectares, an overall rise of about 102.30 per cent, with the sharpest single-year increase of 25.00 per cent occurring in 2005-06 and a large contraction of 12.64 per cent in the very first year of the series (2004-05). Production increased from 4,918.40 thousand tonnes to 15,817.96 thousand tonnes, an overall increase of about 221.61 per cent, again outpacing the growth in area by a wide margin.

Productivity in the district rose from 56.60 tonnes per hectare in 2003-04 to 90.10 tonnes per hectare in 2022-23, an overall increase of about 59.19 per cent, the largest relative productivity gain among the three geographic levels examined. Productivity crossed 100 tonnes per hectare in several years between 2012-13 and 2017-18, before falling back sharply in 2018-19 (-18.52%) and recovering thereafter. Because the growth in production in Kolhapur exceeded that of area by the widest margin of the three units studied, and because productivity itself registered the highest overall gain, the expansion of sugarcane output in the district reflects a

comparatively stronger yield contribution than at either the state or the national level.

The decline recorded in the terminal year of the series, area down by 1.12 per cent, production down by 7.75 per cent and productivity down by 6.42 per cent in 2022-23, follows a period of unusually heavy and erratic monsoon rainfall in the district and the wider western Maharashtra region. Maharashtra received about 120 per cent of its average rainfall between June and October 2022, with natural disasters affecting roughly 2.5 million hectares of cropped area across the state in that period alone. In low-lying and river-adjointing sugarcane tracts of Kolhapur, along the Panchganga and Krishna basins, this excess rainfall caused prolonged waterlogging and, in several pockets, flooding of standing sugarcane fields, which damaged the crop, encouraged fungal infection in submerged fields, and reduced both the sugarcane weight harvested per hectare and its sugar recovery. These conditions were part of the same erratic-rainfall pattern that pulled down Maharashtra's overall sugar output by about 8 per cent in the 2022-23 season, and they illustrate the district's continuing exposure to flood risk even as its long-term productivity trend has remained upward.

Table 3: Area, Production and Productivity of Sugarcane in Kolhapur District (2003-04 to 2022-23)

Year	Area ('000 ha)	% change	Production ('000 Tonnes)	% change	Productivity (Tonnes/ha.)	% change
2003-04	87.00	-	4918.40	-	56.60	-
2004-05	76.00	-12.64	6529.40	32.75	85.58	51.20
2005-06	95.00	25.00	7229.30	10.72	76.50	-10.61
2006-07	106.00	11.58	8573.30	18.59	80.65	5.42
2007-08	114.00	7.55	9742.60	13.64	85.54	6.06
2008-09	103.00	-9.65	8461.30	-13.15	82.55	-3.50
2009-10	113.00	9.71	9810.00	15.94	87.05	5.45
2010-11	140.00	23.89	12591.00	28.35	90.00	3.39
2011-12	146.00	4.29	12847.20	2.03	87.93	-2.30
2012-13	142.00	-2.74	13739.10	6.94	96.75	10.03
2013-14	135.00	-4.93	13580.20	-1.16	100.45	3.82
2014-15	146.00	8.15	15031.60	10.69	102.75	2.29
2015-16	145.00	-0.68	13097.70	-12.87	90.14	-12.27
2016-17	133.00	-8.28	12499.00	-4.57	94.24	4.55
2017-18	144.00	8.27	14779.00	18.24	102.70	8.98

2018-19	149.00	3.47	12491.75	-15.48	83.68	-18.52
2019-20	140.00	-6.04	11384.12	-8.87	81.03	-3.17
2020-21	158.00	12.86	14699.90	29.13	93.18	14.99
2021-22	178.00	12.66	17146.73	16.65	96.28	3.33
2022-23	176.00	-1.12	15817.96	-7.75	90.10	-6.42

(Source - Department of Economics and Statistics, DAC, New Delhi.)

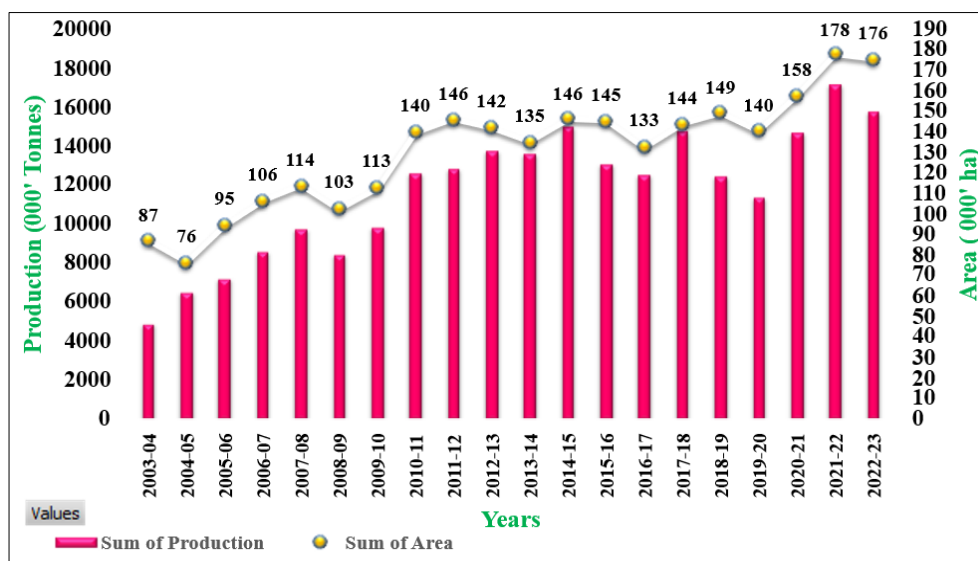


Fig 4: Trends in Area and Production of Sugarcane in Kolhapur District

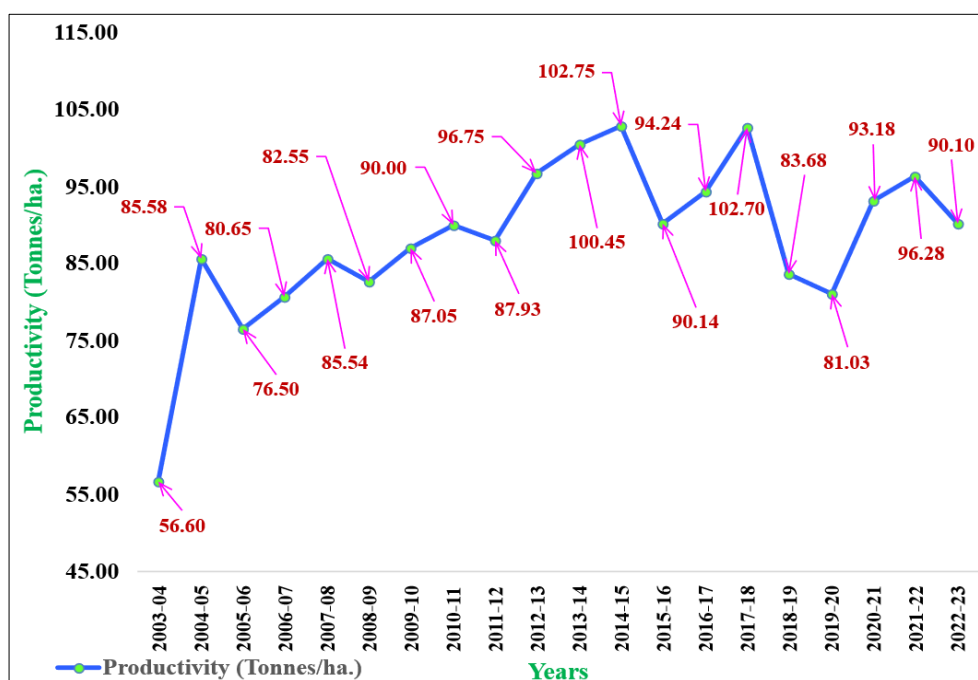


Fig 5: Trends in Productivity of Sugarcane in Kolhapur District

3.4 Comparative Growth and Instability of Area, Production and Productivity

Table 4 summarises the compound annual growth rate (CAGR) and coefficient of variation (CV) in area, production and productivity of sugarcane at the national, state and district levels. At the all-India level, area grew at a modest 0.88 per cent per annum, production at 2.22 per cent per annum and productivity at 1.33 per cent per annum, all significant at the 1 per cent level, indicating that national output growth over the reference period was driven more by productivity gains than by area expansion. In sharp contrast, both Maharashtra and Kolhapur exhibited markedly area-and-production-led growth: area in Maharashtra grew at 2.57 per cent and production at 3.29 per cent per annum (productivity only

0.70%, significant at 5%), while in Kolhapur district area grew at 3.54 per cent, production at 4.85 per cent and productivity at 1.26 per cent per annum, all significant at the 1 per cent level. Kolhapur thus recorded the fastest growth in every parameter among the three units studied.

The coefficient of variation confirms that area and production were considerably more unstable than productivity at every level examined. Instability in area and production was lowest for India (CV of 9.02% and 15.79% respectively) and progressively higher moving from the state to the district level (Maharashtra: 23.29% and 26.40%; Kolhapur: 21.17% and 28.27%), while productivity remained comparatively stable throughout (CV ranging from 7.62% in Maharashtra to 11.90% in Kolhapur). This pattern suggests that as the unit of

analysis narrows from the national to the district level, sugarcane cultivation becomes more sensitive to localised factors such as water availability, sugarcane pricing by individual sugar factories and competition from alternative crops, even though the underlying yield base remains relatively stable due to irrigation assurance and adoption of high-yielding varieties such as Co 86032 in areas like Kolhapur.

Table 4: Growth and Instability of Area, Production and Productivity of Sugarcane in India, Maharashtra and Kolhapur

	Particulars	India	Maharashtra	Kolhapur
CAGR	Area	0.88***	2.57***	3.54***
	Production	2.22***	3.29***	4.85***
	Productivity	1.33***	0.70**	1.26***
CV (%)	Area	9.02	23.29	21.17
	Production	15.79	26.40	28.27
	Productivity	8.95	7.62	11.90

(***, ** Significant at 1% and 5% level, respectively.)

4. Conclusion

- At the national level, sugarcane production grew at a compound annual growth rate (CAGR) of 2.22 per cent per annum, driven mainly by gains in productivity (1.33% CAGR) rather than expansion of area (0.88% CAGR), with a corresponding CV of 9.02, 15.79 and 8.95 per cent for area, production and productivity, respectively — indicating that national output growth was productivity-led and accompanied by comparatively low instability.
- In Maharashtra, sugarcane production grew at a CAGR of 3.29 per cent per annum, driven mainly by expansion of area (2.57% CAGR) rather than gains in productivity (0.70% CAGR), with a corresponding CV of 23.29, 26.40 and 7.62 per cent for area, production and productivity, respectively — reflecting area and production-led growth accompanied by moderate instability in area and production.
- In Kolhapur district, sugarcane production grew the fastest among the three units, at a CAGR of 4.85 per cent per annum, driven mainly by expansion of area (3.54% CAGR) rather than gains in productivity (1.26% CAGR), with a corresponding CV of 21.17, 28.27 and 11.90 per cent for area, production and productivity, respectively — again reflecting area-led growth accompanied by relatively higher instability in production.
- At all three levels, area and production were considerably more unstable than productivity, and this instability increased as the unit of analysis narrowed from the country to the district; a common factor behind this pattern is the continuing influence of monsoon variability, water availability and sugarcane-pricing policy on farmers' area-allocation decisions.
- Kolhapur district recorded the highest productivity among the three levels, with productivity rising from 56.60 to 90.10 tonnes per hectare (an overall increase of about 59.19 per cent), attributable to assured irrigation along the Panchganga and Krishna river basins and the adoption of high-yielding varieties such as Co 86032. Given that yield gains, where they occurred, were comparatively more stable than area-driven gains, policies aimed at strengthening irrigation assurance, promoting high-yielding varieties and stabilising sugarcane-pricing arrangements would help convert the observed area-led growth in Maharashtra and Kolhapur

into more sustainable, yield-led growth in the years ahead.

5. suggestions

1. Strengthening irrigation and climate-resilient water management

Farmers should be encouraged to adopt efficient irrigation systems such as drip irrigation, proper water scheduling and rainwater harvesting to reduce the impact of drought, excess rainfall and waterlogging on sugarcane area and production.

2. Promoting productivity-oriented cultivation and improved varieties

Greater emphasis should be given to the adoption of high-yielding and climate-resilient sugarcane varieties, balanced nutrient management and improved agronomic practices to enhance productivity and reduce dependence on expansion of cultivated area for increasing sugarcane production.

3. Timely and remunerative sugarcane pricing

Stable and remunerative sugarcane prices should be ensured to reduce fluctuations in farmers' decisions regarding area allocation and to encourage sustainable sugarcane cultivation.

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