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Dynamics of area, production, and productivity of medicinal plants in Haryana: An econometric investigation into growth and instability

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Abstract

Medicinal plants play a crucial role in the global healthcare system and rural economy. This study examines the dynamics of area, production, and productivity of medicinal crops over a 23-year period (2003-2025). Utilizing Compound Annual Growth Rate (CAGR) and the Cuddy-Della Valle Index (CDVI), the study assesses growth performance and degree of instability across four distinct time periods. The results reveal a highly volatile sector characterized by extreme production spikes and periods of significant contraction, followed by a robust recovery in the most recent quinquennium (2021-2025). The findings underscore the need for policy interventions to stabilize yields and incentivize sustainable cultivation.

Keywords: CDVI, Growth trend, Medicinal plants, CAGR

1. Introduction

The medicinal and aromatic plant (MAP) sector has gained global prominence due to the rising demand for natural healthcare products and herbal supplements. While the sector offers high economic returns compared to traditional cereal crops, it is often plagued by market volatility and environmental sensitivities. Understanding long-term trends in area and productivity is essential for stakeholders to manage risks. This paper analyzes the growth trajectories and instability inherent in medicinal data from 2003 to 2025, providing insights into the historical shifts and future potential of the industry. Previous studies on medicinal crop economics often highlight the "boom and bust" cycles associated with niche agricultural markets. Researchers have noted that while the area under cultivation often responds to market price signals, productivity remains hampered by a lack of standardized cultivation practices and quality seeds. Studies using CAGR and CV (Coefficient of Variation) have frequently shown that medicinal plants exhibit higher instability compared to food grains, primarily due to the specialized nature of the harvest and sensitivity to climatic shifts.

Recent studies indicate a gradual but significant shift in Haryana's cropping patterns. While the Green Revolution initially favored a wheat-paddy monoculture, researchers like Nimbrayan *et al.* (2019) ^[4] have noted that post-Green Revolution periods have seen a diversification toward niche crops. Specifically for medicinal plants, the growth in area and production is driven by the rising global demand for herbal formulations. However, this growth is often characterized as "sporadic" rather than "linear," influenced heavily by volatile market prices and government subsidies. The state of Haryana, traditionally known for its "Green Revolution" crops (wheat and rice), has seen a gradual diversification into medicinal and aromatic plants (MAPs) such as Aloe Vera, Isabgol, Ashwagandha, and Stevia. Studies indicate that the Aravalli hills and the semi-arid regions of Southern Haryana (Mahendergarh, Rewari, and Gurgaon) possess significant floral diversity, with over 53 species identified as having high commercial potential (Yadav *et al.*, 2020) ^[8].

Medicinal crops in Haryana face higher instability compared to traditional staples. This is largely due to the lack of regulated "Mandis" (markets) for MAPs, making farmers reliant on private contractors and middle-men (Thanki *et al.*, 2011) ^[7]. Unlike wheat, medicinal plants are highly sensitive to micro-climatic shifts. Research highlights that while they are drought-tolerant, biotic stresses like local pests and lack of standardized quality seeds contribute to production instability (Sindhuja & Malik, 2025) ^[6]. There is an increasing trend toward using

Good Agricultural and Collection Practices (GACP) and organic certification to tap into the export market (CCRAS, 2024). The use of the Cuddy-Della Valle Index (CDVI) in agricultural statistics is a standardized method to distinguish between genuine growth and mere fluctuations. Literature on crop instability in Haryana suggests that while horticultural crops often face high price instability, mushrooms maintain a relatively stable production environment due to controlled indoor conditions. However, structural shifts-such as the transition from seasonal "thatched hut" cultivation to year-round "environmentally controlled units" (ECUs)-introduce phases of variability, which are captured through multi-period instability analysis (Mishra *et al.*, 2021) [3]. The Cuddy-Della Valle Index (CDVI) has been identified as the superior metric for this purpose, as it de-trends the data to prevent the overestimation of instability that often occurs with the standard Coefficient of Variation (Pavani *et al.*, 2025) [5].

Materials and Methods

Data Source and Description

The study is based on secondary time-series data pertaining to the area (in hectares), production (in Metric Tonnes), and productivity (MT/ha) of medicinal crops. The dataset spans 23 years, from 2003 to 2025. To identify shifts in performance over different economic and policy regimes, the timeline was categorized into four distinct analytical periods:

- **Period I:** 2003 to 2010 (Early Phase)
- **Period II:** 2011 to 2020 (Middle Phase)
- **Period III:** 2021 to 2025 (Recent Phase)
- **Overall Period:** 2003 to 2025

Analytical Framework:

Trend Analysis

To examine the long-term, a linear trend model was fitted:

$$Y_t = a + bt + \varepsilon_t$$

where Y_t represents production or productivity or area at time t , a is the intercept, b is the trend coefficient, and ε_t is the random error term.

The sign and magnitude of the coefficient b indicate the

direction and rate of change over time. A positive value of b indicates an increasing trend, while a negative value indicates a declining trend.

Compound Annual Growth Rate (CAGR)

The CAGR was used to estimate the steady rate of growth over the specified periods, smoothing out annual fluctuations. It is expressed as using a semi-log (log-linear) model: $\ln(Y_t) = \alpha + \beta t$

The compound annual growth rate (CAGR) was computed as: $CAGR = (e^\beta - 1) \times 100$

This method captures the exponential growth pattern and provides a more accurate measure of growth over time compared to simple averages.

Measurement of Instability

Instability in medicinal plants was measured using both the coefficient of variation (CV) and the Cuddy-Della Valle Index (CDVI).

The coefficient of variation was calculated as: $CV = \frac{\sigma}{\mu} \times 100$, where σ is the standard deviation and μ is the mean.

To account for the effect of trend in the data, the Cuddy-Della Valle Index was used:

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

where R^2 is the coefficient of determination obtained from the trend regression. The CDVI provides a more reliable measure of instability by eliminating the influence of long-term trend.

Results and Discussion

Trend Fitting

A linear trend analysis was conducted to determine the long-term direction and consistency of the medicinal sector's growth between 2003 and 2025. This analysis uses the linear equation $y = a + bt$, where b represents the annual rate of change (slope).

Summary of Linear Trend Statistics

Table 1: Annual Change in Area, Production, and Productivity with Statistical Significance

Variable	Annual Change (Slope)	R-squared (R^2)	P-value	Significance
Area (in ha)	-74.89	0.349	0.0029	Significant Decline
Production (MT)	-149.06	0.008	0.6771	Not Significant
Productivity (MT/ha)	+0.049	0.036	0.3826	Not Significant

The linear trend analysis confirms that while the Area of medicinal plants has been steadily shrinking over the long term, yield efficiency (Productivity) is struggling to find a consistent upward path. The massive discrepancy in

production trends suggests that the sector is highly susceptible to "shocks"-extraordinary years of high output followed by significant drops-making it difficult for the industry to follow a predictable growth trajectory.

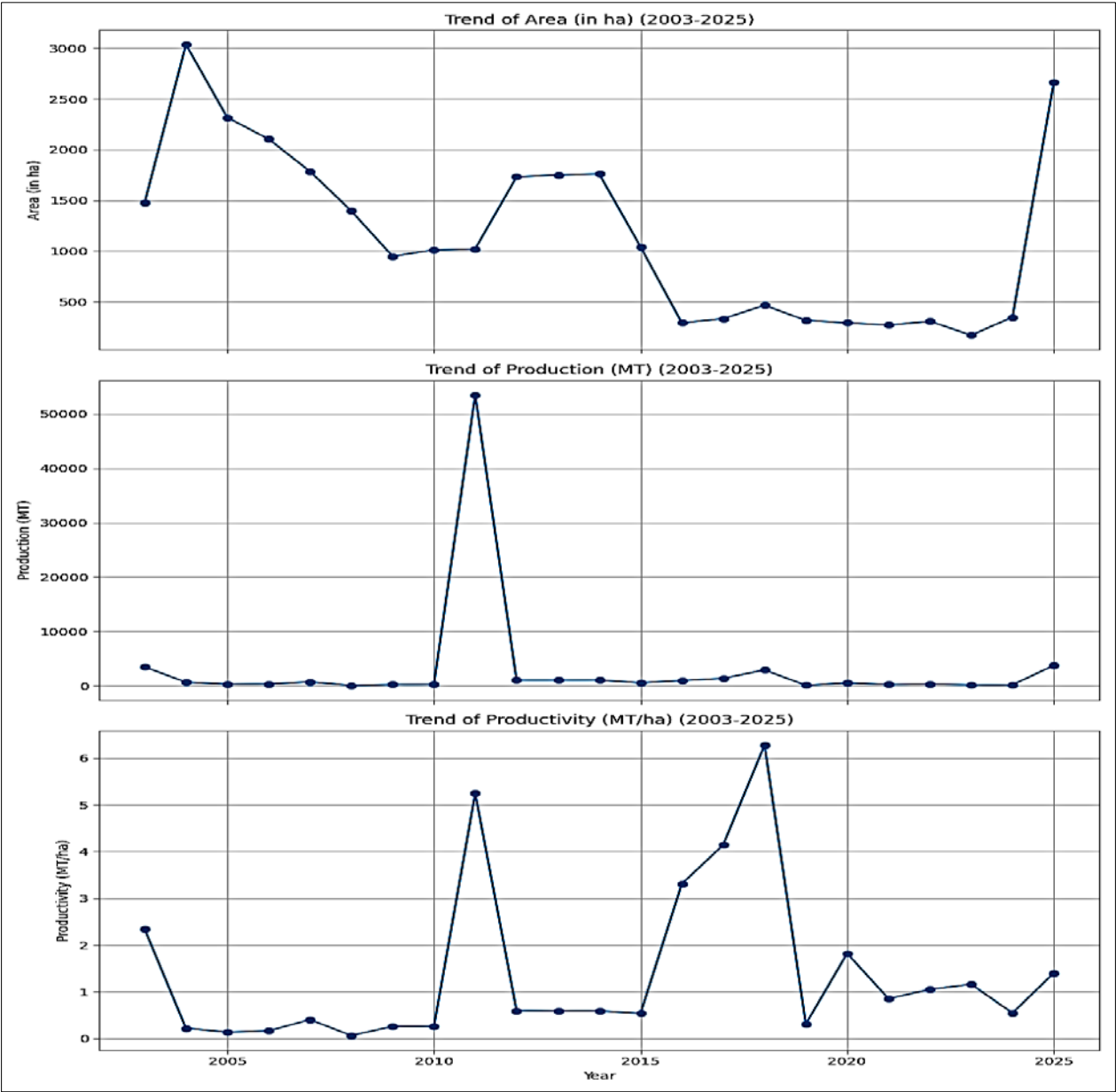


Fig 1: Trends in Area, Production, and Productivity from 2003 to 2025

Growth Rate Analysis (CAGR) and Instability Analysis (CDVI)

The analysis of medicinal plant cultivation data from 2003 to

2025 provides a comprehensive look at the sector's performance, characterized by significant shifts in growth and stability. The results are summarized in Table and illustrated through comparative growth and instability charts.

Table 1: CAGR, Coefficient of Variation (CV), and Cropping Diversity Instability (CDVI) for Area, Production, and Productivity across Different Periods (2003-2025)

Period	Variable	CAGR (%)	CV (%)	CDVI (Instability)
2003-2010	Area (in ha)	-5.28	40.16	28.95
	Production (MT)	-30.99	145.72	110.48
	Productivity (MT/ha)	-27.14	158.18	131.79
2011-2020	Area (in ha)	-13.01	72.12	44.17
	Production (MT)	-40.1	263.37	224.61
	Productivity (MT/ha)	-11.1	95.48	95.21
2021-2025	Area (in ha)	77.5	142.68	100.04
	Production (MT)	101.24	167.82	120.75
	Productivity (MT/ha)	13.29	32.36	30.98
2003-2025	Area (in ha)	2.72	73.72	59.46
	Production (MT)	0.36	343.14	341.69
	Productivity (MT/ha)	-2.31	123.39	121.12

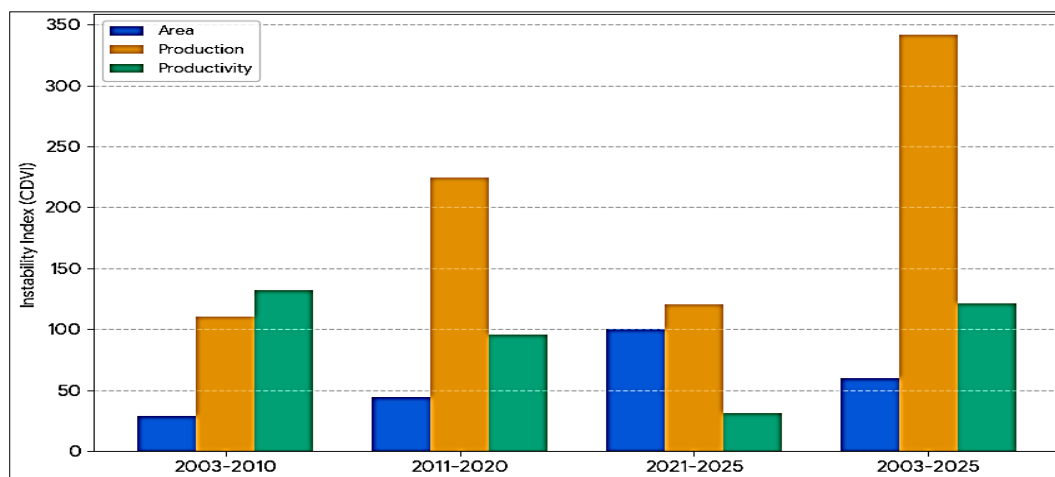


Fig 1: Instability Index (CDVI) by Period

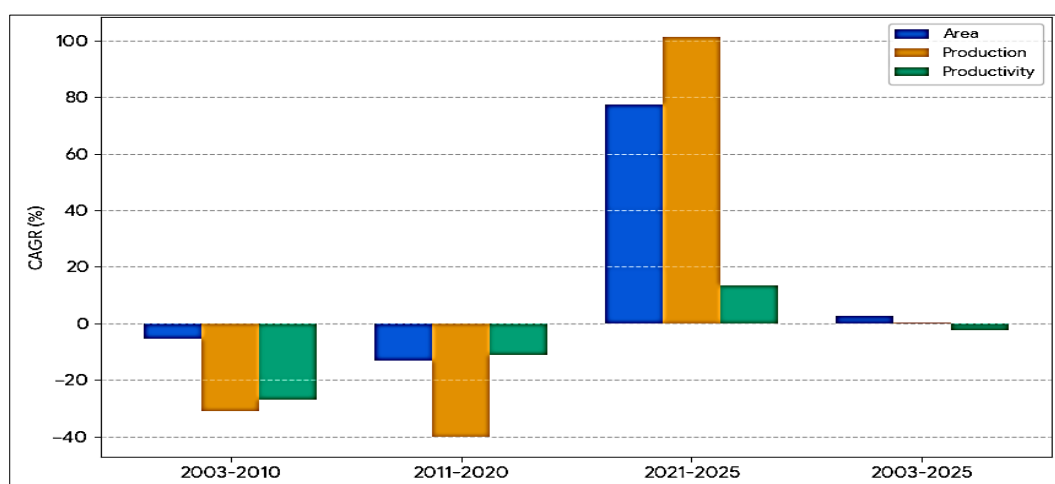


Fig 2: Compound Annual Growth Rate (CAGR) by Period

Growth Trends (CAGR)

The Compound Annual Growth Rate (CAGR) reveals three distinct phases of the industry:

- **Decline Phase (2003-2020):** During the first two periods, the sector witnessed a consistent contraction. The area decreased by -5.28% and -13.01% respectively. The most dramatic decline was seen in production, which plummeted by over 30-40% annually in these periods. This could be attributed to market saturation, shifting farmer preferences toward commercial horticulture, or lack of institutional support during this time.
- **Expansion Phase (2021-2025):** The recent data indicates a massive surge in both area (77.50%) and production (101.24%). This "v-shaped" recovery suggests a significant policy intervention or a market-driven boom in medicinal plant demand (possibly influenced by the post-pandemic global shift toward herbal and traditional medicine).
- **Long-term Growth (2003-2025):** Over the entire 23-year span, the overall CAGR for the area is positive at 2.72%, while production growth is stagnant at 0.36%. Productivity, however, shows a long-term negative growth rate of -2.31%, indicating that while more land is being utilized, the average yield per hectare has not kept pace with the expansion.

Instability Analysis (CDVI)

The Cuddy-Della Valle Index (CDVI) provides a clearer picture of the risks associated with medicinal cultivation by adjusting for the trend.

- **Production Volatility:** Production has remained the most unstable parameter. In Period II (2011-2020), instability reached an alarming index of 224.61, primarily driven by extreme outliers (such as the 53,523 MT spike in 2011 followed by sharp drops). For the entire duration, the production instability index is 341.69, categorized as extremely high instability.
- **Productivity Stabilization:** Interestingly, while productivity was highly unstable in the early years (CDVI of 131.79), it has become significantly more stable in the recent period (2021-2025) with a CDVI of 30.98. This suggests that contemporary farming practices or better crop varieties are leading to more predictable yields despite the rapid expansion in area.
- **Area Instability:** The instability in land allocation reached its peak in the most recent period (100.04), reflecting the rapid and perhaps speculative expansion of medicinal crop farming in the 2020s.

Conclusion

The medicinal plant sector has transitioned from a period of high instability and negative growth to a phase of rapid

expansion in the 2020s. While the growth in the last five years is promising, the extreme historical instability in production indicates a fragile supply chain. To sustain the current growth trend, policy measures should focus on crop insurance, price stabilization, and the dissemination of high-yield, stress-resistant varieties.

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