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Comparative analysis of growth and instability in grape production across selected districts of North and South Karnataka

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ABSTRACT

The present study examined the growth and instability in grape production across selected districts of North Karnataka (Vijayapura, Belagavi and Bagalkot) and South Karnataka (*Chikkaballapura* and Bengaluru Rural) using secondary time-series data obtained from the Directorate of Horticulture, Government of Karnataka. District-level data covered 2003-04 to 2023-24 (2007-08 to 2023-24 for *Chikkaballapura*), and a common period of 2007-08 to 2023-24 was used for regional comparison. The compound annual growth rate (CAGR) was estimated using a log-linear regression model, while production instability was assessed through the coefficient of variation (CV) and the Cuddy-Della Valle instability index (CDVI). A region $\times$ time interaction model was fitted to test differences in growth rates between the two regions. Among North Karnataka districts, Vijayapura recorded the highest and statistically significant growth rate (15.25 per cent per annum), followed by Belagavi (11.48%) and Bagalkot (8.20%). In South Karnataka, Bengaluru Rural showed a significant growth rate of 1.95 per cent, whereas *Chikkaballapura* recorded a non-significant growth of 1.49 per cent. Instability was highest in Vijayapura (CV: 94.86%; CDVI: 46.32%) and lowest in Bengaluru Rural (CV: 15.01%; CDVI: 8.89%) among all the districts studied. During the common period, North Karnataka recorded a substantially higher regional CAGR (14.45%) than South Karnataka (1.62%), a difference confirmed as highly significant ($p < 0.001$) by the region $\times$ time interaction. North Karnataka also exhibited greater production instability (CV: 73.44%; CDVI: 30.36%) compared with South Karnataka (CV: 17.46%; CDVI: 15.30%). The findings indicate that the faster expansion of grape production in North Karnataka was accompanied by considerably greater year-to-year fluctuations, while South Karnataka showed slower but comparatively more stable growth. These contrasting patterns underline the need for region-specific strategies, with North Karnataka requiring stronger production-risk management, efficient irrigation and post-harvest infrastructure, and South Karnataka benefiting from improved production technologies and market linkages to sustain growth. The study highlights the importance of jointly considering growth and instability while assessing the regional performance of horticultural crops.

Keywords: Growth rate, Instability, Cuddy-Della Valle index, Log-linear regression

Introduction

Grape (*Vitis vinifera* L.) is an important commercial fruit crop cultivated for fresh consumption, processing and export. Globally, grape production was about 77.7 million tonnes in 2024, while India produced approximately 3.90 million tonnes during 2023-24 (OIV, 2025; Indiatat, 2025) [2, 1]. Comparatively Karnataka found one of the important grape-producing state in India, with production of about 10.5 lakh tonnes in recent estimates (NRC Grapes, 2024) [3]. Within Karnataka, grape production is distributed across several districts, with important production centres in both northern and southern regions. During 2023-24, Vijayapura recorded grape production of about 8.69 lakh tonnes, followed by Belagavi (1.37 lakh tonnes) and Bagalkot (0.75 lakh tonnes) in North Karnataka. In South Karnataka, *Chikkaballapura* and Bengaluru Rural recorded production of about 0.81 and 0.46 lakh tonnes, respectively (Directorate of Horticulture, 2024) [4]. Thus, the selected districts of North Karnataka together accounted for 10.81 lakh tonnes, whereas the selected districts of South Karnataka accounted about 1.27 lakh tonnes of grape production during 2023-24.

The magnitude of production alone does not adequately describe the performance of a production region. Growth analysis indicates the rate and direction of change in production over time, while instability analysis measures fluctuations in production around the underlying trend. These measures are useful for assessing the long-term production performance of commercial horticultural crops and for understanding regional variation in production dynamics. Several studies have examined the growth and instability of grape production in India and Karnataka. Devaraj (2020) [5] reported positive growth in grape production in Karnataka during 2004-05 to 2018-19 and highlighted the changing production performance of the crop over time duration. Sathyendra Kumar *et al.* (2022) [6] reported a significant annual growth rate of 7.96 per cent in grape production in Karnataka, with production instability estimated at 13.72 per cent. Recently, Kencharaju *et al.*

(2025) [7] reported a compound annual growth rate of 6.09 per cent in grape production in Karnataka during 1991-92 to 2021-22. These studies indicate considerable temporal changes in grape production in Karnataka, but the magnitude of growth and instability may considerably vary among production regions.

Research gap

Previous studies have mainly examined grape production growth and instability at the state, division or individual district level. However, limited studies have directly compared the growth and instability of grape production among selected districts of North and South Karnataka using a specific study period. Differences in production magnitude may not necessarily correspond to variation in growth rate or production stability. Therefore, a regional comparison is effectively required to quantify the differences in grape production growth and instability between the two selected regions. In view of this the present study was undertaken with the specific objectives:

1. To estimate the growth rate of grape production in selected districts of North and South Karnataka.
2. To assess the instability in grape production across the selected districts.
3. To compare the growth and instability of grape production between Districts of North and South Karnataka.

Materials and methods

Study area and data source

The study was conducted to assess the growth and instability of grape production in selected districts of North and South Karnataka. Vijayapura, Belagavi and Bagalkot were selected from North Karnataka, while Chikkaballapura and Bengaluru Rural were selected from South Karnataka. Secondary data on annual grape production were obtained from the Directorate of Horticulture (Planning), Department of Horticulture, Government of Karnataka, Bengaluru. The data covered the period 2003-04 to 2023-24 for Vijayapura, Belagavi, Bagalkot and Bengaluru Rural, whereas data for Chikkaballapura were available from 2007-08 to 2023-24. For effective comparison between the two selected regions, the common period of 2007-08 to 2023-24 was considered. Regional production was obtained by summing the annual production of the selected districts within each region. Similar use of secondary time-series data for assessing growth and instability of agricultural and horticultural production has been reported in previous studies (Sathyendra Kumar *et al.*, 2022; Nagaveni *et al.*, 2024; Ralte, 2023) [6, 8, 9].

Growth analysis

The compound annual growth rate (CAGR) of grape production was estimated using the log-linear regression model, which is widely used for estimating compound growth in agricultural time series data (Sathyendra Kumar *et al.*, 2022; Mishra *et al.*, 2025) [6, 10].

The model was specified as:

$$\ln(Y_t) = a + bt + \varepsilon_t$$

where, Y_t : Grape production in year t , a : Intercept, b : Regression coefficient representing the instantaneous growth rate and ε_t : Random error term.

The compound annual growth rate was calculated as:

$$CAGR = (e^b - 1) \times 100$$

The estimated regression coefficient b was tested for statistical significance using the Student's t -test. A probability level of $p < 0.05$ was considered statistically significant. The same log-linear approach and significance testing have been used in agricultural growth studies involving production time series (Sathyendra Kumar *et al.*, 2022; Wani *et al.*, 2024) [6, 11].

Instability analysis

Production instability was assessed using the coefficient of variation (CV) and the Cuddy-Della Valle instability index (CDVI). The coefficient of variation was calculated as:

$$CV = \frac{SD}{\bar{Y}} \times 100$$

where SD : Standard deviation and $\bar{Y}$: Mean production.

Since the coefficient of variation may overstate instability in time-series data having a systematic trend, the Cuddy-Della Valle index (CDVI) was used as the principal measure of production instability (Cuddy *et al.*, 1978) [12].

The CDVI was calculated as:

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

where R^2 indicates the coefficient of determination obtained from the fitted time trend regression. The index adjusts the coefficient of variation for the effect of the underlying trend, thereby providing a more appropriate measure of instability in time-series agricultural data (Cuddy *et al.*, 1978; Ralte, 2023) [12, 9]. A higher CDVI value indicates greater production instability, whereas a lower value indicates relatively greater stability. The CDVI has been widely applied in studies of both agricultural and horticultural crops, including grape production in Karnataka (Sathyendra Kumar *et al.*, 2022; Nagaveni *et al.*, 2024) [6, 8].

Regional comparison

For regional comparison, annual grape production of the selected districts was aggregated separately for North Karnataka and South Karnataka over the common period of 2007–08 to 2023–24. Mean production ($\bar{x}$), standard deviation (SD), CV , $CAGR$ and $CDVI$ were estimated for each selected region.

To formally test whether the growth rates of grape production differed between the two regions, a log-linear regression model incorporating a region $\times$ time interaction term was fitted using

$$\ln(Y_t) = \beta_0 + \beta_1 t + \beta_2 R + \beta_3 (t \times R) + \varepsilon_t$$

where ' R ' denotes the regional group and ' $t \times R$ ' represents the interaction between time and region. The significance of the interaction coefficient ' β_3 ' was used to determine whether the production growth rates differed significantly between North and South Karnataka regions.

Statistical analysis

The analysis carried out consisted of three components: (i) $CAGR$ for measuring production growth, (ii) CV and $CDVI$ for measuring production instability, and (iii) a region $\times$ time interaction model for testing differences in regional growth rates. These approaches are consistent with established methods used for analysing growth and instability in agricultural production (Cuddy *et al.*, 1978; Sathyendra Kumar *et al.*, 2022; Nagaveni *et al.*, 2024; Ralte, 2023) [12, 6, 8, 9].

Result and discussion

Growth in grape production

The compound annual growth rates of grape production for the selected districts are presented in Table 1. Among the North Karnataka districts, Vijayapura recorded the highest growth rate of 15.25 per cent per annum, followed by Belagavi (11.48%) and Bagalkot (8.20%). The growth coefficients were statistically significant at the 5 per cent level, indicating a sustained increase in grape production over the respective study periods.

In South Karnataka, Bengaluru Rural recorded a significant positive growth rate of 1.95 per cent per annum, as compared to *Chikkaballapura* registered a growth rate (1.49 % per annum), establishing statistically non-significant ($p > 0.05$). Thus, although production in *Chikkaballapura* increased over the study period, the observed increase was not sufficiently consistent to establish a statistically significant compound growth.

The comparatively higher growth rates observed in the selected North Karnataka districts may be associated with the expansion and intensi-

fication of grape production in the region. In particular, the high growth observed in Vijayapura indicates a substantial increase in grape production over the study period. The positive growth observed in Belagavi and Bagalkot also indicates continued expansion of grape production in these districts. Similar positive growth in grape production in Karnataka has been reported by Devaraj (2020) [5] and Sathyendra Kumar *et al.* (2022) [6], although the magnitude of growth differs across study periods and geographical units.

Table 1. Growth in grape production in selected districts of North and South Karnataka

Regions	Selected Districts	Study period	Mean Production (MT)	CAGR (%)	Significance
North Karnataka	Vijayapura	2003–04 to 2023–24	246,729.50	15.25	Significant
	Belagavi	2003–04 to 2023–24	50,596.01	11.48	Significant
	Bagalkot	2003–04 to 2023–24	38,095.43	8.20	Significant
South Karnataka	<i>Chikkaballapura</i>	2007–08 to 2023–24	65,089.00	1.49	Non-Significant
	Bengaluru Rural	2003–04 to 2023–24	36,478.71	1.95	Significant

Note: Significant at $p < 0.05$, MT: Metric tonnes

Instability in grape production

The variability and instability estimates are presented in Table 2. Among the selected districts, Vijayapura recorded the highest coefficient of variation (94.86%) and Cuddy–Della Valle instability index (46.32%). This indicates that grape production in Vijayapura experienced considerable year-to-year fluctuations despite the strong positive long-term growth.

Belagavi recorded a coefficient of variation of 68.99 per cent and a CDVI of 25.74 per cent, while Bagalkot recorded 51.32 per cent and 20.09 per cent, respectively. The lower CDVI of Bagalkot compared with Vijayapura and Belagavi indicates relatively lower fluctuation after accounting for the underlying trend.

Among the South Karnataka districts, *Chikkaballapura* recorded a CV of 26.05 per cent and a CDVI of 24.77 per cent, whereas Bengaluru Rural recorded substantially lower values of 15.01 per cent and 8.89 per cent, respectively. The relatively low CDVI in Bengaluru Rural indicates that its grape production fluctuated less around the underlying trend during the study period.

The differences between CV and CDVI across districts also demonstrate the importance of accounting for the underlying trend when measuring instability. The present findings are consistent with earlier studies that have identified variability in grape production across Karnataka and emphasized the usefulness of trend-adjusted measures of instability (Cuddy *et al.*, 1978; Sathyendra Kumar *et al.*, 2022) [12, 6].

Table 2. Instability in grape production in selected districts of North and South Karnataka

Regions	Selected Districts	Mean production (MT)	SD (MT)	CV (%)	R ² value	CDVI (%)
North Karnataka	Vijayapura	246,729.50	234,041.50	94.86	0.762	46.32
	Belagavi	50,596.01	34,907.81	68.99	0.861	25.74
	Bagalkot	38,095.43	19,551.28	51.32	0.847	20.09
South Karnataka	<i>Chikkaballapura</i>	65,089.00	16,958.52	26.05	0.096	24.77
	Bengaluru Rural	36,478.71	5,477.08	15.01	0.649	8.89

Note: CDVI = Cuddy-Della Valle Instability Index.

Comparative growth and instability between North and South Karnataka

For a meaningful regional comparison, the common period **2007–08 to 2023–24** was used. The results are presented in Table 3. During this period, the selected districts of North Karnataka recorded a mean annual grape production of **3.93 lakh tonnes**, compared with **1.03 lakh tonnes** in the selected districts of South Karnataka.

The estimated CAGR was 14.45 per cent per annum for North Karnataka, while South Karnataka recorded a CAGR of 1.62 per cent per annum. Both regional growth rates were statistically significant. Furthermore, the region $\times$ time interaction in the log-linear model was highly significant ($p < 0.001$), confirming that the production growth rates differed significantly between the two regions.

Table 3. Regional comparison of growth and instability in grape production for the period 2007–08 to 2023–24

Region	Mean production (lakh tonnes)	CV (%)	CAGR (%)	R ² value	CDVI (%)
North Karnataka	3.93	73.44	14.45	0.8290	30.36
South Karnataka	1.03	17.46	1.62	0.2330	15.30

Note: CAGR significant at $p < 0.05$ for both regions. Difference in regional growth rates was significant based on the region $\times$ time interaction ($p < 0.001$).

The regional results indicate that grape production in the selected North Karnataka districts increased at a substantially higher rate than that observed in South Karnataka districts during the common study

period. At the same time, North Karnataka exhibited greater production variability, with a CV (73.44 %) and CDVI (30.36 %), compared to South Karnataka (CV = 17.46 % and CDVI = 15.30 %).

The higher growth accompanied by greater instability in North Karnataka suggests that the increase in production was associated with considerable year-to-year fluctuations. In contrast, the selected South Karnataka districts recorded a comparatively lower production growth rate with lower overall variability. The regional differences noticed in the present research study extend the findings of earlier Karnataka-level studies by demonstrating that grape production dynamics can differ considerably across geographical regions within the state (Devaraj, 2020; Sathyendra Kumar *et al.*, 2022) [5, 6].

Overall finding

Overall, the Statistical analysis showed significant positive growth in grape production in Vijayapura, Belagavi, Bagalkot and Bengaluru Rural, while Chikkaballapura district showed a positive but non-significant growth rate ($p > 0.05$). Among the districts, Vijayapura exhibited both the highest production growth and the highest instability. At the regional level, the selected North Karnataka districts recorded a significantly higher production growth rate than the selected South Karnataka districts, but also showed greater production instability. These findings demonstrate that growth and stability followed different patterns across the two regions, highlighting the importance of considering both measures when assessing the long-term performance of grape production.

Conclusion

The study revealed distinct differences in grape production growth and instability between the selected districts of North and South Karnataka. In North Karnataka districts, Vijayapura (15.25%), Belagavi (11.48%) and Bagalkot (8.20%) recorded significant positive growth rates. In South Karnataka, Bengaluru Rural recorded significant growth of 1.95 per cent, while the growth in Chikkaballapura (1.49%) was non-significant. During the common period of 2007–08 to 2023–24, North Karnataka recorded a substantially higher production growth rate (14.45%) than South Karnataka (1.62%), and the region $\times$ time interaction was highly significant ($p < 0.001$), confirming a significant difference in growth rates between the two regions selected.

Production instability also varied considerably across the selected districts. North Karnataka recorded higher regional variability (CV = 73.44%; CDVI = 30.36%) compared with South Karnataka (CV = 17.46%; CDVI = 15.30%). Among the districts, Vijayapura showed the highest instability, whereas Bengaluru Rural recorded the lowest. Overall, the findings demonstrate that the selected North Karnataka districts experienced faster grape production growth but greater temporal fluctuations, while South Karnataka districts exhibited relatively gradual growth with lower variability. These differences exclusively highlight the need for region-specific strategies that combine production expansion with risk management and production stabilisation.

Policy implications

- a. **North Karnataka Region:** The high growth and relatively high instability of grape production in North Karnataka call for greater emphasis on production-risk management, efficient irrigation, climate-resilient practices, crop insurance and strengthening of post-harvest infrastructure to stabilise production and manage increasing output.

- b. **South Karnataka Region:** The relatively low growth and lower production instability in South Karnataka indicate scope for improving production technologies, strengthening extension services, efficient resource utilisation, value addition and market linkages to support sustained growth in grape production.

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