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An Economic Analysis of Growth and Instability of Vegetable Production in Eastern India

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ABSTRACT

Background: The study examined the patterns of growth and volatility in vegetable production within India. The instability observed in vegetable production has led to significant disruptions in both supply and farm earnings. This escalating volatility in agricultural production, prices and farm income has raised apprehensions. The research assesses the expansion and instability in the cultivation of specific vegetables, Brinjal (*Solanum melongena*), Cabbage (*Brassica oleracea*), Onion (*Allium cepa*), Okra (*Abelmoschus esculentus*) as well as the aggregate vegetable output from the period spanning 1994-95 to 2021-22 in India.

Methods: The findings pertaining to growth (CAGR) patterns reveal a sense of inconsistency across regions, despite heightened production and increased cultivation areas dedicated to vegetables and witnessed significant increase in growth of vegetable production in India.

Result: The analysis of instability highlights that the states of Odisha, Bihar and West Bengal exhibit relatively lower susceptibility to instability compared to Uttar Pradesh and Chhattisgarh, states with larger cultivation areas. The state-level analysis does not reflect the complete picture of problems in vegetable production and production problems under estimates affects to farm income. Need for addressing risks in farm income by devising area-specific crop insurance or other suitable mechanisms.

Key words: CAGR, Instability, Production, Vegetable.

INTRODUCTION

India, the primary centre of origin and secondary centre of many vegetable crops, also possesses large variability in many important introduced vegetable crops. Globally, vegetable production has recorded intensive growth on a per capita basis. This trend is particularly strong in developing countries. India has witnessed a significant increase in vegetable production over the last two decades (IIVR, 2019). Vegetables can transform our food systems towards healthier diets and more sustainable production systems while creating value and job opportunities (Anbukkarasi *et al*. 2013). Vegetables cover 34.41 per cent of the world's total agricultural area. This trend is particularly strong in developing countries. India has witnessed a significant increase in vegetable production over the last two decades. The production of vegetables has increased from 93.85 million tonnes in 2000-2001 to 334.60 million tonnes in 2021-22. The horticulture growth is a sunrise along with the food grain production of country and has been giving it a tough competition Fig 1.

The consumption pattern of fruits and vegetables per person was associated with the countries' socio-economic status where the low-income countries have lower consumption per capita than high-income countries (Dubowitz *et al.*, 2008, Pessoa *et al.*, 2015, Miller *et al.*, 2016). The country's diverse climate offers a vast production base for vegetables. Globally it ranks second in vegetable production; however, the county is the largest producer of Okra and ranks second in the production of green peas, tomato, cabbage, cauliflower and brinjal. India witnesses nearly 4.6-15.9% wastage in fruits and vegetables annually, due to lack of modern harvesting practices and inadequate cold chain infrastructure (Opportunities in Fruits and Vegetables Sector in India, 2017). The export and import of fresh and processed vegetables have increased with the liberalisation, globalisation and ease of trade restrictions (Iswarya *et al*. 2024). The existence of a vast production base offers India tremendous opportunities for export. During 2019-20, India exported vegetables worth Rs. 12,146.32 Crore/ USD 1,511.14 Millions (APEDA, 2022). Even though India's share is merely 1 per cent globally, there is still acceptance of its horticulture product. The projected forecast

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of vegetables and fruits of the Indian scenario representsa promising exponential growth system Fig 2.

Despite progress in irrigation and technology, agriculture production and income are subject to a large year-to-year fluctuations, playing havoc with farmers' livelihood and adversely affecting their decisions to invest in farming (Chand *et al.,* 2008). The food production and agriculture industries can implement adaptation practices that ensure an increase in food production with lower environmental burdens (Tuomisto *et al.,* 2008). Moreover, Timmer (2005) stated that variation or instability in agricultural production is an important issue to be discussed because of volatility in agricultural production due to existence of external shocks (Kaur and Kaur, 2024).

Several attempts have been made to examine the extent of instability in the food grains in India (Mehra, 1981; Hazell, 1982, Dev, 1987, Chand and Raju, 2008). However, in case of vegetables, not many extensive researches have been conducted. The paper deals with the strategies to mitigate the risk and develop a better understanding of risk management.

The study has estimated the growth trend and instability analysis at the major vegetable producing states of eastern India, particularly Bihar, Chhattisgarh, Odhisa, Uttar Pradesh and West Bengal for vegetable crops, particularly Brinjal, Cabbage, Onion, Okra and total vegetables. It has explored how vegetable production's growth and instability have coalesced the risk at the state level.

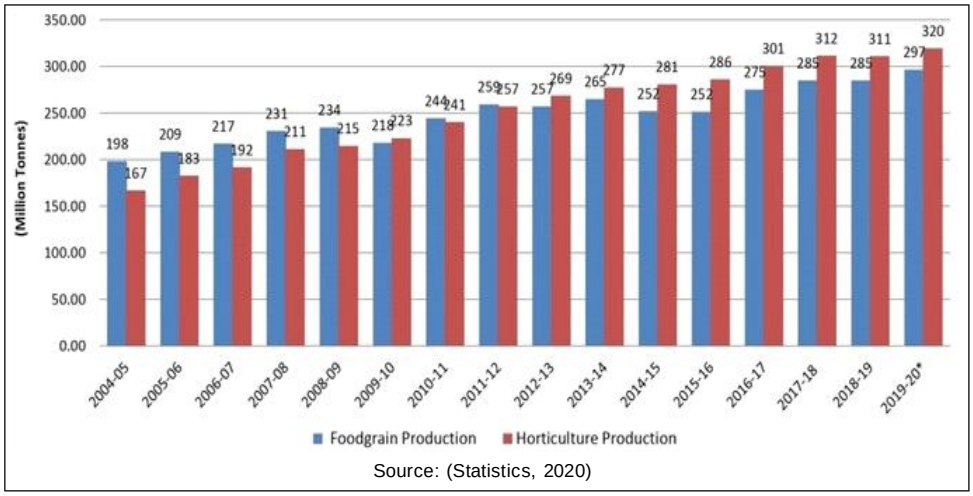
MATERIALS AND METHODS

The paper has used time-series data on area, production and yield at the state levels as well as national level for Brinjal, Cabbage, Onion, Okra and the respective state's total vegetables. The data is referred from the National Horticulture Board (various issues) and Ministry of Agriculture and Farmers Welfare, Government of India. The analysis was conducted for the data covering the time period of 1994-95 to 2020-21 for both the state and national level. The states under study have been chosen purposively as they exhibited high acreage in terms of area and production.

Compound annual growth rate (CAGR)

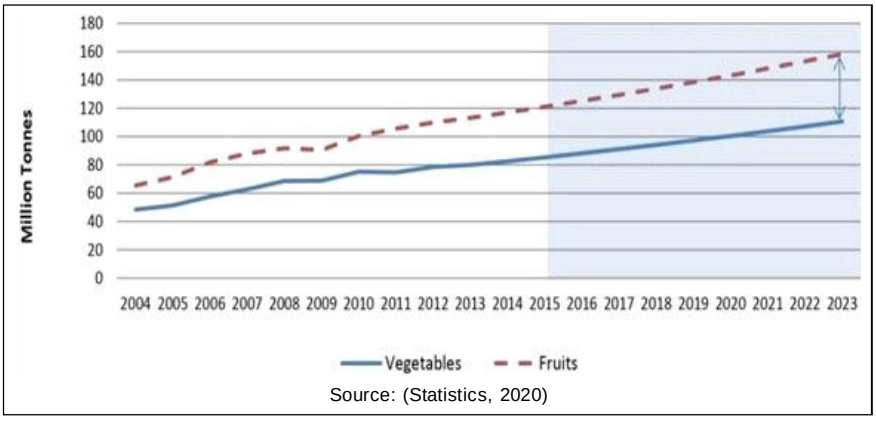
The compound annual growth rate was computed by fitting the following exponential functions below.

The function takes the form of a linear equation in logarithmic form and becomes log-linear as under:



Source: (Statistics, 2020)

Fig 1: Food grain production and horticulture production.



Source: (Statistics, 2020)

Fig 2: Projected production of vegetables and fruit in India.

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

$$\text{Compound growth rate (CGR)} = (Antilog\ \beta\text{-}1) \times 100$$

Where:

Y= Trend value of dependent variable (area/ total production/ yield).

a= Constant.

b= Trend coefficient (slope of the line).

t= Time variable (Years).

The t-test performed to test the significance of β.

For this analysis, the Growth rate values (in per cent) are divided into three groups, which indicate the different ranges of growth rates Table 1.

The index of instability was computed in order to examine the nature and degree of instability in the area, production and yield of concerned vegetables in India at major producing states levels. A linear trendy = a+bt +e fitted to the indices of area, production and productivity and trend co-efficient b' was tested. For a better measure of variability, we adopted the instability index, which was developed by Cuddy and Della (1978).

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

Table 1: Ranges of growth rates in area, production and yield, in per cent.

Range of instability	Per cent
Low growth rate	0 to 10
Moderate growth rate	10 to 20
High growth rate	>20

Source: Author's Calculation.

Table 2: Ranges of instability indices per cent.

Ranges of instability	Per cent
Low degree of instability	0 to 10
Medium degree of instability	10 to 20
High degree of instability	>20

Source: Author's Calculation.

Where, II-Instability Index.

CV - Coefficient, variation.

$\bar{R}^2$- Coefficient determination from a time-trend regression adjusted by the number of degrees offreedom.

The measure uses a variable over time that should satisfy two minimum properties to estimate instability. Firstly, it should not include deviations in the data series that arise due to secular trend or growth. Secondly, it should be comparable across data sets having different means (Chand and Raju, 2009). For this analysis, the Instability Index values (in per cent) are divided into three groups, which indicate the different range of instability Table 2.

Decomposition analysis

Decomposition analysis was used in order to measure the area effect, yield effect and production effect and the relative percentage contribution of area and yield towards the change in total vegetable output. The change in vegetable production during any time period was decomposed into different components in the following manner which was used by Allauddin and Tisdell (1986).

$$\Delta P = [A_o * \Delta Y] + [Y_o * \Delta A] + [\text{“}A * \Delta Y]$$

Change in production =

Yield effect +Area effect + Interaction effect

P_o, A_o and Y_o = Area, production and yield in the base year.

P_n, A_n and Y_n = Area, production and yield in a current year.

RESULTS AND DISCUSSION

The main focus of this paper was to examine the year-to-year fluctuations in vegetable production and their effect on the instability in crop output. Accordingly, instability in the area, production and yield of major vegetable crops of eastern India were studied at the national level and state-level during the time period (1994-95 to 2021-22).

Growth, Instability and Decomposition of Brinjal in major the states of India

The current status as well as the past performance of the crucial vegetables *viz.* Brinjal, Cabbage, Onion, Okra and

Table 3: Compound annual growth rates and instability indices of brinjal for different states for the period (1994-95 to 2021-22).

States		Area	Production	Yield
Uttar Pradesh	CAGR	0.006*	-1.978	-1.997
	Instability Index	36.02	36.25	29.89
West Bengal	CAGR	2.814***	4.848***	1.975***
	Instability Index	12.19	20.13	11.7
Odisha	CAGR	-0.464	1.377***	1.849***
	Instability Index	6.59	10.52	5.43
Chhattisgarh	CAGR	2.867***	4.710***	1.793***
	Instability Index	9.77	13.24	6.47
Bihar	CAGR	-1.074	-0.869	0.205
	Instability Index	13.06	8.66	11.82
Total India	CAGR	2.320***	3.152***	0.817
	Instability Index	1.1	2.07	2.46

***, ** and * Significant at one, five and ten per cent level.

total vegetables of the major vegetable producing states of eastern India were analysed. During the period 1994 to 2021, the compound growth rate was examined in area, production and productivity of major vegetables. The maximum growth rate was recorded (Table 3) for Brinjal in West Bengal for area and production at (4.84 per cent) and (1.975 per cent) respectively. In contrast, the yield was highest in the case of Odisha (1.975). This yield was higher than the national level average of the total brinjal production; Uttar Pradesh and Bihar recorded negative numbers in area and production.

The Instability in area, production and yield of brinjal has been presented in Table 3. The instability index at national level was reported to be the least for area at 1.10 per cent, followed by 2.07 per cent in production and 2.46 per cent in yields.

In state-wise study, the instability was reported maximum in the case of Uttar Pradesh for area, production as well as yield; followed by West Bengal, which exhibited the highestinstability in terms of the growth rates.

A perusal of Table 4 revealed the decomposition analysis of brinjal, where the estimates of the area effect were highest in the case of Uttar Pradesh which exhibited the least growth rate and highest instability. Despite showing a greater level of instability, West Bengal still has the highest share of the interaction effect.

Growth, instability and decomposition of cabbagein major the states of India

A perusal of the Table 5 revealed a negative growth coupled with high degree of instability in case of Uttar Pradesh for area, production as well as yield. The state of West Bengal

Table 4: Decomposition of change in production of brinjal in different states (1994-95 to 2020-21) for the period.

State	Brinjal		
	Area effect	Yield effect	Interaction effect
Uttar Pradesh	82.78	14.80	2.22
West Bengal	25.26	40.27	34.47
Odisha	169.09	-49.70	-18.71
Chhattisgarh	26.45	49.87	23.69
Bihar	-56.55	148.94	7.55
All India	15.39	73.77	11.46

Table 5: Compound annual growth rates and instability indices of cabbage for different states for the period (1994-95 to 2021-22).

States		Area	Production	Yield
Uttar Pradesh	CAGR	-10	-10.7	-0.6
	Instability Index	69.86	72.94	38.04
West Bengal	CAGR	3.1***	5.6***	2.4***
	Instability Index	15.11	24.03	18.24
Odisha	CAGR	-0.9	0.8	1.7***
	Instability Index	12.16	16.8	12.33
Chhattisgarh	CAGR	8.3***	7.0***	-1.2
	Instability Index	9.82	40	35.33
Bihar	CAGR	-0.1	0.6*	0.8*
	Instability Index	7.59	9.39	3.67
India	CAGR	2.99***	3.55***	0.55***
	Instability	2.44	3.15	5.72

***, ** and * Significant at 1, 5 and 10% level.

Table 6: Decomposition of change in production of cabbage in different states (1994-95 to 2021-22) for the period.

States	Cabbage		
	Area effect	Yield effect	Interaction effect
Uttar Pradesh	25.8	70.2	4.02
West Bengal	24.02	27.19	48.83
Odisha	152.02	-28.87	-23.38
Chhattisgarh	-16.07	183.55	-67.51
Bihar	37.98	42.62	19.49
India	19.86	63.92	16.69

witnessed a positive and high growth rate; however, it too was coupled with a high level of instability. Chhattisgarh recorded the highest growth rate in area and production with 8.3 per cent and 7.0 per cent , respectively but suffered from a high degree of instability. The national average was positive and significant and had a relatively low degree of instability. The estimation of decomposition analysis results in Table 6 revealed the highest interaction effect under West Bengal with 48.83 per cent and highest area contribution was under Bihar with 37.89 per cent and maximum yield effect at the national level with 63.92 per cent.

Growth, instability and decomposition of onionin major the states of India

A perusal of Table 7 revealed that Bihar outshined the rest of the states in all three measurement statistics of area, production and yield with 6.73 per cent, 13.11 per cent and 5.98 per cent, respectively. The national aggregate result of onion was also promising, with a 9.26 per cent growth in production. As compared to the rest of the states, there is a moderate rise in the growth rate of Chhattisgarh coupled with a low level of instability. The growth and instability results of Uttar Pradesh showed a negative growth in area accentuated with a high degree of instability.

The decomposition analysis revealed a negative yield and interaction effect under Uttar Pradesh (Table 8). The maximum area contributing to the production was under West Bengal with 26.06 and the contribution of yield was highest in Odisha with 51.89 and the interaction effect was maximum in Bihar.

Growth, instability and decomposition of okra in major the states of India

A perusal of Table 9 depicting the growth rate and instability of Okra, it was observed that Bihar exhibited the highest growth rate in the area, production and yield wit 6.73 per cent, 13.11 per cent and 5.98 per cent respectively. Next to Bihar is the national aggregate of Okra for area, production and yield with values 6.21 per cent, 9.26 per cent and 2.88 per cent respectively. West Bengal and Uttar Pradesh both exhibit low growth rate and high instability. Chhattisgarh had a moderate growth rate in area and production and a negative growth rate in yield. The decomposition analysis results Table 10 further revealed an approximated production contribution of area and yield was 47.39 and 42.43 for India.

Growth, instability and decomposition of total vegetables in major the states of India

The growth and instability of the total vegetables in the concerned states understudy was estimated as in Table 11. The state of Chhattisgarh was in the lead with the highest growth rate under area and production at 13.76 per cent and 13.71 per cent respectively and West Bengal exhibited the highest growth rate in yield at 1.57 per cent. Highest instability was observed in Uttar Pradesh for production, Odisha for area and West Bengal in yield. The state of

Table 7: Compound annual growth rates and instability indices of onion for different states for the period (1994-95 to 2021-22).

States		Area	Production	Yield
Uttar Pradesh	CAGR	-0.64	1.39**	2.08***
	Instability Index	31.14	21.19	13.28
West Bengal	CAGR	2.72***	4.15***	1.63***
	Instability Index	13.97	34.19	11.26
Odisha	CAGR	-0.79	2.18***	2.99***
	Instability Index	26.74	24.27	15.87
Chhattisgarh	CAGR	4.00***	3.39***	-0.59
	Instability Index	5.92	9.59	9.57
Bihar	CAGR	6.73***	13.11***	5.98***
	Instability Index	25.66	33.57	17.15
India	CAGR	6.21***	9.26***	2.88***
	Instability Index	3.54	5.18	3.82

***, ** and * Significant at 1, 5 and 10% level.

Table 8: Decomposition of Change in Production of Onion in different states the period (1994-95 to 2021-22).

States	Onion		
	Area effect	Yield effect	Interaction effect
Uttar Pradesh	112.01	-8.12	-3.44
West Bengal	26.06	45.95	27.90
Odisha	25.68	51.89	19.84
Chhattisgarh	-11.65	131.69	-20.03
Bihar	24.00	26.69	49.32
India	16.12	47.93	35.83

Table 9: Compound annual growth rates and instability indices of okra for different states for the period (1994-95 to 2021-22).

States		Area	Production	Yield
Uttar Pradesh	CAGR	-0.64	1.39***	2.08***
	Instability index	31.14	21.19	13.28
West Bengal	CAGR	2.72***	4.15***	1.63**
	Instability index	13.97	34.19	11.26
Odisha	CAGR	-0.79	2.18***	2.99***
	Instability index	26.74	24.27	15.87
Chhattisgarh	CAGR	4.00***	3.39***	-0.59
	Instability index	5.92	9.59	9.57
Bihar	CAGR	6.73***	13.11***	5.98***
	Instability index	25.66	33.57	17.15
India	CAGR	6.21***	9.26***	2.88***
	Instability index	3.54	5.17	3.81

***, ** and * Significant at one, five and ten per cent level.

Table 10: Decomposition of change in production of okra in different states the period (1994-95 to 2021-22).

States	Okra		
	Area effect	Yield effect	Interaction effect
Uttar Pradesh	33.67	34.09	17.33
West Bengal	10.14	78.26	11.78
Odisha	-5.57	105.00	0.98
Chhattisgarh	3.89	88.42	7.73
Bihar	26.95	78.99	-5.70
India	47.39	42.43	10.61

Table 11: Compound annual growth rates and instability indices of total vegetables for different states for the period (1994-95 to 2021-22).

		Area	Production	Yield
Uttar Pradesh	CAGR	2.21***	1.28**	0.68
	Instability index	15.4	69.67	14.8
West Bengal	CAGR	5.58***	4.78***	1.57**
	Instability index	19.51	44.63	36.44
Odisha	CAGR	-1.18	0.31*	1.51**
	Instability index	49.83	-13.81	27.55
Chhattisgarh	CAGR	13.76***	13.71***	-0.05
	Instability index	10.66	8.61	8.57
Bihar	CAGR	1.17***	2.65***	1.44**
	Instability index	11.76	5.92	1.92

***, ** and *Significant at one, five and ten per cent level.

Table 12: Decomposition of change in production of total vegetables in different states the period (1994-95 to 2021-22).

States	Total vegetables		
	Area	Yield	Interaction
	Effect	Effect	Effect
Uttar Pradesh	15.40	69.67	14.80
West Bengal	19.51	44.63	36.44
Odisha	49.83	-13.81	-63.98
Chhattisgarh	0.66	90.61	8.57
Bihar	91.76	5.92	1.92

Bihar was found to be having a moderate growth rate and moderate instability. The decomposition analysis (Table 12) further showed that the maximum area contribution in production is from Bihar and the maximum yield effect is from Chhattisgarh.

Association between growth rate and instability

A perusal of Table 13 shows the grouping of concerned vegetables of Eastern India by combining different growth rates and instability index in vegetable production in the concerned states. In the case of Brinjal, the national level area production was found to be showing high growth rate

Table 13: Association between growth rate and instability of vegetable production*.

Vegetable crop	Brinjal			Cabbage			Onion			Okra			Total vegetables		
Type of association#	A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
High growth rate and high instability		W.B.			C.G.		B.R.	WB, B.R.		B.R.	W.B., B.R.				
Medium growth rate and high instability								UP., O.D.			O.D.	O.D.			WB
Low growth rate and high instability	U.P.	U.P.	U.P.	U.P.	U.P.	U.P., C.G.	U.P.	OD.		UP, OD			OD	UP	OD
High growth rate and moderate instability	W.B.	C.G.		W.B.	W.B.	W.B.	W.B.		O.D., B.R.		U.P.	B.R.	CG		
Medium growth rate and moderate instability			W.B.			O.D.			U.P.	W.B.		U.P, WB	U.P., W.B, B.R.		
Low growth rate and moderate instability	B.R	O.D.	B.R.	O.D.	O.D.				W.B.						UP
High growth rate and low instability	India	India		CG India	India	India	C.G. India	C.G. India	India	C.G. India	C.G. India	C.G. India		WB, C.G., B.R	
Medium growth rate and low instability	C.G.		India												BR

Note: B.R.- Bihar, C.G.- Chhattisgarh, O.D.-Odhisa, UP- Uttar Pradesh, W.B.- West Bengal

A-Area, **P**-Production, **Y**-Yield

* The relationship between growth rate and instability is proposed to understand the relationship between both the variables in the states among vegetables under consideration

Type of association is author's own calculation for association among the variables of growth rate, instability, states and vegetables as a whole.

and low instability. The state of Uttar Pradesh was found to have a low growth rate and high instability indices in all the three dimensions of the area production and yield. Bihar and Chhattisgarh show moderate growth rates and a medium level of instability.

The situation in case of cabbage crop also provides similar results for Uttar Pradesh, while West Bengal exhibited a high growth rate coupled with medium instability. The national level average for cabbage exhibits a positive trait with high growth rate and low instability.

In case of Onion and Okra, the national average showed the same positive trait. The state of Chhattisgarh was found to be showing a high growth rate associated with low indices of instability. While analysing the case of total vegetables, Uttar Pradesh, West Bengal and Bihar showed a medium growth rate and moderate instability in the case of area and High growth rate and low instability in Bihar, Chhattisgarh and West Bengal. Low growth rate and low instability were observed in case of production in the state of Odisha and yield in Chhattisgarh. The state-level analysis of the association between growth rate and instability analysis showed a wide range of fluctuation among different crops. The instability was low when the growth rate was also low and instability was high when the growth rate was also high.

The compound growth rates and instability indices in vegetable production across states and crops, including brinjal, cabbage, okra and onion show that despite urbanization, vegetable production area grew in India and the area under study, with slow diversification in Bihar and Uttar Pradesh. Brinjal cultivation was found to have increased in West Bengal, surpassing the national average. However, production alone does not ensure access. Odisha and Chhattisgarh showed progress despite varying growth patterns. Positive growth rates were noted for onions and okra. Vegetable cultivation area were observed to have increased due to research and technology, but post-harvest systems showed some need in strengthening due to perishability (Anonymous 2017; Ahmad *et al*., 2018).

Losses due to pests, diseases and transportation were highlighted by (Gupta *et al*., 2021), with significant proportions lost in brinjal and okra, echoing Ahmad *et al*.'s findings. This underscores the urgency for technology and infrastructure improvement to minimize losses and promote vegetable cultivation. Contract farming could aid small farmers with inputs and guidance (Gupta *et al*., 2021). In essence, the study emphasizes on growth, instability trends and the need for enhanced technology and contract farming to encourage sustainable vegetable production and reduce losses (Chand and Raju, 2008; Murshid *et al*., 2013). Implementation of comprehensive post-harvest technologies and infrastructure to minimize losses and enhance quality in vegetable supply chains, while simultaneously promoting contract farming initiatives to provide small and marginal farmers with technical support, quality inputs and financial assistance, thereby fostering sustainable vegetable cultivation.

CONCLUSION

Vegetable production dynamics in major Eastern Indian states, exhibited diverse growth rates and instability levels. While progress has been made in production and area expansion, challenges like post-harvest losses, pests and transportation persist, leading to wastage. Brinjal's mixed trends and promising growth in onions and okra underscore the potential for improvement. High growth rates can lead to instability due to external shocks, demanding technological innovation, infrastructure investment and support for contract farming. By enhancing post-harvest practices, fostering collaboration and advancing supply chains, Eastern India's vegetable sector can become more resilient and efficient. Addressing growth and instability is pivotal. This study stresses the importance of targeted measures for sustainable and efficient vegetable production in the region, aligning with food security goals.

Author's contribution

All authors contributed toward data analysis, drafting and revising the paper and agreed to be responsible for all aspects of this work.

Declarations

Author(s) declare that all works are original and this manuscript has not been published in any other journal.

Conflict of interest

The authors declare that they have no conflicts of interest to report regarding the present study.

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