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Food Instability Dynamics in Indian Fruits and Vegetables

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ABSTRACT

Background: India is one of the world's largest producers of fruits and vegetables, yet fluctuations in area, production and productivity continue to create uncertainty in farm incomes, market supply and food security. Understanding the level and pattern of instability across states is therefore essential for balanced horticultural development.

Methods: The study assesses state-wise instability in the production of fruits and vegetables in India over the period 2001-2021, covering 27 central states. Time-series data on area, production and productivity were compiled from official sources. The Cuddy-Della Valle Index (CDVI) was used to measure instability after adjusting for time trends and instability levels were classified as low, moderate and high to facilitate meaningful comparison across states and periods.

Result: Results indicate that at the national level, both fruits and vegetables remained within the low instability level across all three dimensions, though fruits showed relatively higher instability in area and productivity, while vegetables showed comparatively higher instability in production. At the state level, several states recorded high instability levels. Maharashtra showed high instability in fruit area (33.85%). Arunachal Pradesh showed high instability in fruit production (54.18%), vegetable area (51.05%) and productivity (75.87%), while Nagaland showed high instability in fruit productivity (64.54%) and vegetable production (46.82%). These findings indicate that instability is concentrated in specific regions, particularly in northeastern and hill states, reflecting structural and agro-climatic constraints. The results highlight the need for state-specific crop planning, promotion of climate-resilient and high-yielding varieties, strengthened extension services and improved market infrastructure.

Key words: Cuddy-della valle index, Food, Fruits, Instability, State-wise analysis, Vegetables.

INTRODUCTION

Agriculture remains a cornerstone of India's economy, supporting a large share of the population and contributing significantly to national income (Baruah and Mandal, 2025; Sidhu, 2025). Within this framework, fruits and vegetables have emerged as dynamic components of the agricultural sector due to their role in income diversification, nutritional security and export expansion (Gupta, 2022). India is the second-largest producer of horticultural crops globally, including fruits, vegetables, spices and plantation crops. As per the National Horticultural Database (2021-22), fruit production reached 102.48 million metric tonnes from 9.6 million hectares, while vegetable production stood at 200.45 million metric tonnes from 10.86 million hectares. These commodities and their processed products account for nearly 55 per cent of India's agricultural exports, highlighting their economic significance.

The rapid growth of the horticultural sector reflects broader structural shifts in the Indian economy (Bhuyan and Kotoky, 2023; Kaur and Goyal, 2025). Rising incomes, urbanization, dietary diversification and integration with global markets have accelerated demand for high-value agricultural commodities. For farmers, diversification toward fruits and vegetables offers opportunities for higher returns and value addition. However, this growth trajectory is accompanied by spatial and temporal variability in area, production and productivity.

Agricultural production instability carries significant economic consequences. Fluctuations in output generate income uncertainty for producers, contribute to price volatility, influence investment behaviour and affect export

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reliability. Persistent variability may also signal structural inefficiencies, including inadequate infrastructure, climatic vulnerability and market imperfections. Economic theory suggests that sustainable agricultural development requires not only growth but also stability, as predictable production patterns support investment, technological adoption and food security (Singh and Byerlee, 1990; Weber and Sievers, 1985).

Although prior studies have examined growth performance and export trends in India's horticultural sector (Bhuyan and Kotoky, 2023), most analyses are confined to national aggregates. Such approaches often mask substantial inter-state disparities arising from differences in agro-climatic conditions, resource endowments, infrastructure and technological adoption. The limited focus on state-level instability restricts the development of region-specific policy interventions to reduce risk and strengthen production systems.

In this context, the present study assesses state-wise instability in area, production and productivity of fruits and vegetables in India by constructing an instability index. It compares the magnitude of variability across central producing states, classifies states by the degree of instability observed and examines the economic implications of this instability for food security and sustainable sectoral growth.

MATERIALS AND METHODS

The study covers 27 Indian states. Goa was excluded due to its negligible contribution to total fruit and vegetable production and the unavailability of consistent time-series data. For states formed after 2001, data were merged with their respective parent states (*e.g.*, Telangana with Andhra Pradesh and Uttarakhand with Uttar Pradesh) for the earlier years to ensure continuity and comparability across the entire study period. This harmonization avoids structural breaks in the time series and maintains analytical consistency.

The states included in the analysis are Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand and West Bengal.

The study covers the period from 2001 to 2021 using annual time-series data on area, production and

Table 1: Instability index (CDVI) of fruits in area.

States	Period-I (2001-2011)	Period-II (2011-2021)	Overall period (2001-2021)
Andhra Pradesh	14.454	11.320	12.984
Arunachal Pradesh	6.104	14.637	27.556
Assam	9.886	1.709	7.800
Bihar	3.940	4.777	4.669
Chhattisgarh	16.263	4.180	15.996
Gujarat	24.776	2.429	6.892
Haryana	14.381	3.644	8.803
Himachal Pradesh	8.572	0.609	5.568
Jammu and Kashmir	17.090	11.080	21.833
Jharkhand	29.891	2.485	16.106
Karnataka	6.872	3.575	6.632
Kerala	20.758	18.267	20.924
Madhya Pradesh	30.705	7.290	21.204
Maharashtra	16.758	26.967	33.847
Manipur	28.743	5.703	21.058
Meghalaya	11.738	4.734	8.979
Mizoram	18.400	6.076	14.256
Nagaland	45.541	7.578	27.765
Odisha	4.599	2.637	5.267
Punjab	2.216	1.655	2.670
Rajasthan	19.842	12.822	15.251
Sikkim	23.691	4.109	13.064
Tamil Nadu	5.804	6.843	9.862
Tripura	2.909	13.189	19.921
Uttar Pradesh	5.898	6.280	8.086
Uttarakhand	30.140	5.910	20.664
West Bengal	2.617	1.780	2.329
All India	4.072	5.404	9.073

productivity for fruits and vegetables in India. The study period was divided into Period I (2001-2011) and Period II (2011-2021) for comparative analysis.

Data sources and preprocessing

Time-series data were sourced from Agriculture Statistics at a Glance, Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India and the Handbook of Statistics on Indian States, Reserve Bank of India (Nayak and Singh, 2018). Data preprocessing included standardizing units, addressing minor missing observations through linear interpolation and examining outliers using trend diagnostics and cross-verification with official publications. Productivity was computed as the ratio of production to area. Statistical computations were performed using SPSS and Excel.

Measurement of instability

Instability is a critical parameter in agricultural economics because production is influenced by climatic uncertainty, price fluctuations and structural constraints (Rede *et al*., 2026). Measuring variability provides insight into risk exposure and structural resilience of production systems.

To quantify instability in area, production and productivity, the Cuddy-Della Valle Index (CDVI) was employed (Cuddy and Della Valle, 1978; Singh and Byerlee, 1990). The CDVI is a refined version of the coefficient of variation (CV) that adjusts for deterministic trends in time-series data. Since agricultural output often follows an upward or downward trend, the simple CV may overestimate variability. The CDVI addresses this limitation by incorporating the trend equation's goodness-of-fit.

The Cuddy-Della Valle Index (I_x) was calculated as follows:

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

Where,

CV= Coefficient of variation.

R^2= Adjusted R^2 (ESS/TSS, *i.e*., ratio of explained variation to total variation).

By adjusting for trend effects, the CDVI provides a more accurate measure of pure instability rather than variability arising from systematic growth patterns.

Classification of instability levels

To improve interpretability, instability levels were classified as low (CDVI < 15 per cent), moderate (15-30 per cent) and

Table 2: The state-wise instability index (CDVI) of fruits in production.

States	Period-I (2001-2011)	Period-II (2011-2021)	Overall period (2001-2021)
Andhra Pradesh	14.508	7.991	11.842
Arunachal Pradesh	10.364	24.497	54.182
Assam	7.768	2.749	6.161
Bihar	7.392	6.848	6.894
Chhattisgarh	19.594	7.899	11.453
Gujarat	5.442	5.054	11.123
Haryana	10.928	10.954	25.696
Himachal Pradesh	35.013	28.430	31.172
Jammu and Kashmir	12.320	10.285	11.527
Jharkhand	22.235	3.665	11.382
Karnataka	6.340	4.069	6.229
Kerala	29.108	9.680	27.344
Madhya Pradesh	30.762	7.664	16.537
Maharashtra	7.548	10.243	8.708
Manipur	26.051	7.731	17.593
Meghalaya	11.478	10.036	10.730
Mizoram	45.536	5.801	22.761
Nagaland	84.249	13.612	41.416
Odisha	12.289	5.801	8.820
Punjab	8.968	1.414	4.671
Rajasthan	14.916	12.485	14.330
Sikkim	18.298	23.705	30.180
Tamil Nadu	16.240	8.281	25.517
Tripura	6.871	15.673	17.823
Uttar Pradesh	20.568	10.446	16.039
Uttarakhand	14.716	6.247	14.855
West Bengal	4.971	5.652	5.660
All India	3.146	3.067	3.673

high (>30 per cent) (Malik and Mohanty, 2023; Khan *et al*., 2024). This classification facilitates meaningful comparison across states and periods, enabling identification of relatively stable and highly volatile production systems.

RESULTS AND DISCUSSION

Considering the goals of the current study, data were gathered from various sources. The state-wise instability index of fruits and vegetables was analysed using appropriate statistical methods, based on area, production and productivity (Kaur and Chauhan, 2024; Sethi *et al*., 2025). Agricultural production instability affects price stability and consumption patterns of agricultural commodities (Ahmed *et al*., 2025). Therefore, instability in area, production and productivity of fruits and vegetables was examined at both state and national levels. The Instability Index was computed for Period I (2001-2011), Period II (2011-2021) and the overall period (2001-2021) (Dey *et al*., 2020). The states formed after 2001 were merged with their parental states for consistency and Goa was excluded due to negligible contribution and lack of data. Thus, 27 states were considered. The Cuddy-Della Valle Index (CDVI) was used to measure instability over time (Jambhulkar *et al*., 2023). The study assessed both the magnitude and changes in instability across the two decades in fruits and vegetables (Rani *et al*., 2022).

The state-wise instability index (CDVI) of fruits in the area

The Instability Index (CDVI) of fruits in the area is presented in Table 1. At the national level, fruit area instability was 4.072 per cent in Period I, increased to 5.404 per cent in Period II and reached 9.073 per cent during the overall period. Although the increase between the sub-periods was moderate, the higher overall value indicates cumulative fluctuations over two decades. Compared to production and productivity, area instability was relatively higher, suggesting that changes in land allocation contributed significantly to variability in the fruit sector (Gowri *et al*., 2017).

At the state level, substantial variation is observed. During Period I, Nagaland recorded the highest instability (45.541%), while Punjab recorded the lowest (2.216%) (Sharma *et al*., 2022). In Period II, Kerala showed the highest instability (18.267%), whereas Himachal Pradesh recorded the lowest (0.609%). Over the overall period, Maharashtra recorded the highest instability (33.847%), while West Bengal recorded the lowest (2.329%) (Pal *et al*., 2022). The consistently high instability in

Table 3: The state-wise instability index (CDVI) of fruits in productivity.

States	Period-I (2001-2011)	Period-II (2011-2021)	Overall period (2001-2021)
Andhra Pradesh	6.060	5.824	9.130
Arunachal Pradesh	12.363	17.286	30.505
Assam	7.600	1.338	4.913
Bihar	5.522	9.767	8.656
Chhattisgarh	45.106	6.652	40.299
Gujarat	35.501	2.740	11.176
Haryana	10.360	9.843	17.440
Himachal Pradesh	34.858	28.547	31.823
Jammu and Kashmir	5.380	9.809	12.953
Jharkhand	24.465	4.756	17.674
Karnataka	2.009	3.380	2.674
Kerala	12.851	26.210	24.290
Madhya Pradesh	7.586	12.979	12.106
Maharashtra	23.815	18.909	32.984
Manipur	18.904	4.070	11.884
Meghalaya	7.334	5.873	7.601
Mizoram	48.279	2.787	41.836
Nagaland	99.879	9.570	64.544
Odisha	8.501	2.795	7.068
Punjab	7.186	1.271	6.170
Rajasthan	24.670	13.448	21.583
Sikkim	16.122	23.399	23.458
Tamil Nadu	11.199	7.590	17.280
Tripura	5.556	4.152	7.899
Uttar Pradesh	20.785	6.108	11.806
Uttarakhand	43.135	1.296	32.183
West Bengal	4.823	4.848	5.265
All India	6.390	6.086	7.196

northeastern states and Maharashtra reflects climatic vulnerability, uneven horticultural expansion and structural limitations, while Punjab and West Bengal show more stable land-use patterns.

The state-wise instability index (CDVI) of fruits in production

The Instability Index (CDVI) of fruits in production is presented in Table 2. At the national level, production instability was 3.146 per cent in Period I, slightly declined to 3.067 per cent in Period II and stood at 3.673 per cent during the overall period (Soujanya *et al*., 2023). The marginal decline indicates some stabilization in fruit output. Production instability was lower than area and productivity instability during the overall period (Kumar *et al*., 2021), suggesting that yield adjustments partly offset area fluctuations.

In Period I, Nagaland recorded the highest instability (84.249%), followed by Mizoram (45.536%), while West Bengal (4.971%) and Gujarat (5.442%) recorded the lowest (Norboo, 2023). During Period II, Himachal Pradesh (28.430%) and Arunachal Pradesh (24.497%) recorded the highest, while Punjab (1.414%) and Assam (2.749%) showed the lowest instability (Varalakshmi *et al*., 2023). Overall, Arunachal Pradesh (54.182%) and Nagaland (41.416%) remained most unstable, while Punjab (4.671%) and West Bengal (5.660%) were lowest (Kaur *et al*., 2021).

Most states experienced a decline in instability from Period I to II, though some, including Arunachal Pradesh, Haryana, Maharashtra, Sikkim, Tripura and West Bengal, showed increases. The persistently high instability in northeastern and hill states highlights vulnerability to climatic fluctuations and structural constraints, particularly for perennial crops (Mohan *et al*., 2022).

The state-wise instability index (CDVI) of fruits in productivity

The Instability Index (CDVI) of fruits in productivity is presented in Table 3. At the national level, productivity instability was 6.390 per cent in Period I, declined slightly to 6.086 percent in Period II and was 7.196 per cent during the overall period (Vanitha *et al*., 2021). Productivity instability remained higher than production instability but lower than area instability, indicating that yield variability contributed significantly to overall fruit sector fluctuations.

In Period I, Nagaland recorded the highest instability (99.879%), followed by Mizoram (48.279%), while Karnataka (2.009%) and West Bengal (4.823%) recorded the lowest.

Table 4: The state-wise instability index (CDVI) of vegetables in the area.

States	Period-I (2001-2011)	Period-II (2011-2021)	Overall period (2001-2021)
Andhra Pradesh	28.820	16.348	37.667
Arunachal Pradesh	36.274	56.150	51.053
Assam	19.304	3.719	12.507
Bihar	8.568	3.478	7.573
Chhattisgarh	17.894	5.243	11.388
Gujarat	8.820	6.576	8.038
Haryana	5.041	10.059	12.068
Himachal Pradesh	7.716	3.371	8.865
Jammu and Kashmir	15.894	3.005	15.923
Jharkhand	17.099	7.385	13.603
Karnataka	2.718	8.728	8.072
Kerala	14.149	9.333	19.955
Madhya Pradesh	9.258	5.576	17.967
Maharashtra	10.955	12.139	12.495
Manipur	22.958	30.298	31.483
Meghalaya	7.759	3.681	6.208
Mizoram	62.393	8.895	36.132
Nagaland	42.953	13.130	34.138
Odisha	6.235	2.778	4.995
Punjab	3.677	2.261	6.601
Rajasthan	7.553	13.015	14.304
Sikkim	10.721	27.797	23.321
Tamil Nadu	8.342	13.058	12.871
Tripura	8.604	7.843	10.222
Uttar Pradesh	7.141	14.111	13.017
Uttarakhand	18.670	4.189	11.609
West Bengal	2.550	1.497	2.224
All India	4.930	2.158	3.912

During Period II, Himachal Pradesh (28.547%) and Kerala (26.210%) recorded the highest, whereas Punjab (1.271%) and Uttarakhand (1.296%) recorded the lowest (Jambhulkar *et al*., 2023). Overall, Nagaland (64.544%) and Mizoram (41.836%) remained most unstable, while Karnataka (2.674%) and Assam (4.913%) showed the least instability (Sharma *et al*., 2022).

Most states experienced a decline in productivity instability from Period I to Period II (Dey *et al*., 2020). During the overall period, Maharashtra showed the highest instability in area (33.847%), Himachal Pradesh in production (31.172%) and Nagaland in productivity (64.544%), indicating that instability varies by dimension across states.

The state-wise instability index (CDVI) of vegetables in the area

The Instability Index (CDVI) of vegetable area is presented in Table 4. At the national level, instability declined from 4.930 per cent in Period I to 2.158 per cent in Period II, with an overall value of 3.912 per cent (Shreyana *et al*., 2022). During Period I, Mizoram (62.393%) and Nagaland (42.953%) recorded the highest instability, while West Bengal (2.550%) and Karnataka (2.718%) recorded the lowest (Sharma *et al*., 2022; Pal *et al*., 2022). In Period II, Arunachal Pradesh (56.150%) and Manipur (30.298%) were highest, West Bengal (1.497%) and Punjab (2.261%) lowest (Norboo, 2023). Overall, Arunachal Pradesh showed the highest instability (51.053%), West Bengal the lowest (2.224%) (Pal *et al*., 2022).

The state-wise instability index (CDVI) of vegetables in production

The Instability Index (CDVI) of vegetable production is presented in Table 5. At the national level, instability declined from 7.215 percent in Period I to 1.758 per cent in Period II, with an overall value of 5.009 per cent (Vanitha *et al*., 2021). Nagaland and Mizoram recorded the highest instability, while Himachal Pradesh and Odisha showed the lowest (Sharma *et al*., 2022). In Period II, Arunachal Pradesh and Sikkim were highest, Punjab and Himachal Pradesh lowest (Norboo, 2023).

The state-wise instability index (CDVI) of vegetables in productivity

The instability index (CDVI) for vegetable productivity is presented in Table 6. At the national level, instability declined from 5.041 per cent in Period I to 2.305 per cent in Period II,

Table 5: The state-wise instability index (CDVI) of vegetables in production.

States	Period-I (2001-2011)	Period-II (2011-2021)	Overall period (2001-2021)
Andhra Pradesh	34.985	13.455	30.331
Arunachal Pradesh	32.410	42.425	36.019
Assam	29.425	12.370	22.425
Bihar	12.391	6.352	9.984
Chhattisgarh	13.213	5.477	8.328
Gujarat	10.732	6.009	9.215
Haryana	6.291	9.898	9.866
Himachal Pradesh	3.716	2.782	5.998
Jammu and Kashmir	20.158	3.579	20.151
Jharkhand	20.937	8.643	21.887
Karnataka	12.583	6.181	15.916
Kerala	8.902	25.957	21.132
Madhya Pradesh	12.203	4.630	23.954
Maharashtra	12.562	8.868	11.735
Manipur	26.516	9.786	13.756
Meghalaya	10.771	8.315	8.974
Mizoram	56.083	15.364	37.241
Nagaland	66.590	24.641	46.822
Odisha	4.955	3.828	6.011
Punjab	8.370	2.746	6.406
Rajasthan	13.806	15.479	16.529
Sikkim	14.688	29.892	26.712
Tamil Nadu	10.601	13.870	17.918
Tripura	14.193	7.981	13.927
Uttar Pradesh	8.656	9.631	10.027
Uttarakhand	17.623	5.135	15.605
West Bengal	9.135	5.839	7.310
All India	7.215	1.758	5.009

Table 6: The state-wise instability index (CDVI) of vegetables in productivity.

States	Period-I (2001-2011)	Period-II (2011-2021)	Overall period (2001-2021)
Andhra Pradesh	8.037	9.475	10.464
Arunachal Pradesh	27.331	46.149	75.875
Assam	17.195	11.717	15.656
Bihar	5.281	5.025	5.051
Chhattisgarh	34.716	1.376	24.943
Gujarat	3.689	1.567	4.818
Haryana	6.401	2.419	6.590
Himachal Pradesh	6.323	1.485	4.378
Jammu and Kashmir	12.532	2.909	10.267
Jharkhand	8.715	4.761	13.669
Karnataka	9.680	6.052	11.842
Kerala	7.694	30.526	23.357
Madhya Pradesh	4.820	2.407	11.789
Maharashtra	9.192	9.266	8.969
Manipur	6.861	16.914	18.688
Meghalaya	6.026	7.062	7.916
Mizoram	52.490	13.830	56.832
Nagaland	25.931	16.943	24.918
Odisha	2.802	1.434	3.246
Punjab	8.144	2.119	6.140
Rajasthan	12.428	15.457	16.312
Sikkim	3.695	12.682	9.923
Tamil Nadu	4.179	4.081	7.353
Tripura	6.574	1.214	6.134
Uttar Pradesh	4.200	6.340	5.781
Uttarakhand	14.538	3.764	14.926
West Bengal	9.364	5.886	7.373
All India	5.041	2.305	3.878

with an overall value of 3.878 percent (Vanitha *et al*., 2021). Productivity instability remained lower than area and production instability, indicating relatively stable yield performance in vegetables.

Mizoram and Chhattisgarh recorded the highest instability in Period I, while Odisha and Gujarat recorded the lowest (Sharma *et al*., 2022). In Period II, Arunachal Pradesh and Kerala recorded the highest instability, whereas Tripura and Chhattisgarh recorded the lowest (Norboo, 2023; Jambhulkar *et al*., 2023). In the overall period, Arunachal Pradesh recorded the highest instability (75.875%), while Odisha (3.246%) and Himachal Pradesh (4.378%) recorded the lowest instability (Sharma *et al*., 2022).

Most states showed improvement from Period I to Period II. When comparing fruits and vegetables, fruits generally exhibited higher productivity instability, while vegetables showed relatively greater instability in production during the overall period.

CONCLUSION

This study shows that instability in India's fruit and vegetable sector varies across crops and states. At the national level during 2001-2021, fruits remained within the low instability level in area (9.073%), production (3.673%) and productivity (7.196%), although fluctuations in area and productivity were relatively higher than in production. Vegetables also recorded a low instability level nationally in area (3.912%), production (5.009%) and productivity (3.878%), with production showing comparatively greater variation.

However, state-level results present a different picture. Maharashtra recorded a high instability level in fruit area, Arunachal Pradesh showed a high instability level in fruit production as well as vegetable area and productivity and Nagaland exhibited a high instability level in fruit productivity and vegetable production. These findings confirm that instability is region-specific and more pronounced in certain northeastern and hill states, reflecting structural constraints and agro-climatic uncertainties.

The policy implications of these results are direct and actionable. Higher instability in fruit area and productivity calls for interventions such as promotion of climate-resilient varieties, orchard rejuvenation programmes and assured irrigation support. In vegetables, greater production instability requires improved market intelligence and strengthening of storage and cold chain infrastructure to manage supply fluctuations.

Reducing instability is essential for farmer income security. Expanding crop insurance, region-specific extension services and informed crop planning can lower production risks. Overall, stabilizing fruit and vegetable production can reduce price volatility and enhance national food security.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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