Horticultural Diversification: A Pathway to Agricultural Resilience

by Shivam ^

The article examines the decomposition of agricultural growth from 1992-93 to 2022–23. The analysis highlights that sustained improvements in yield, higher cropping intensity, and a clear shift towards diversification—especially into horticulture—have been the principal drivers of agricultural growth. Encouragingly, small and marginal farmers have also gained from these trends. Government interventions have made efforts to address challenges such as yield fluctuations, limited storage infrastructure, and price volatility in horticulture production.

Introduction

A vibrant agricultural sector remains indispensable in diffusing economic gains to the bottom of the income pyramid, as 46.1 per cent of India's workforce is engaged in agriculture (PLFS, 2023-24). While the sector's share in gross value added (GVA) has shown a gradual moderation[1], its role in fostering inclusive growth and poverty alleviation has been crucial (Kakwani, 1993; Ravallion and Datt, 1996; Thorbecke and Jung, 1994; Soloaga, 2006). In this context, a systematic decomposition of past agricultural growth trends offers valuable insights to guide policy priorities and strategic policy interventions.

This study undertakes the decomposition of agricultural growth over the past three decades (1992-93 to 2022-23), disaggregating it into four key components: area expansion, yield (or technology) improvement, price effects, and crop diversification. To ensure a comprehensive understanding, the study focuses on eight major crops - rice, wheat, pulses, coarse cereals, fruits and vegetables, oilseeds, sugarcane, and tobacco - which collectively account for over 80 per cent of the gross cropped area and 75 per cent of the gross value of output (GVO).[2] The finding disclosed that yield improvements and diversification, particularly towards horticulture, have emerged as the primary engines of agricultural growth, while enhanced cropping intensity[3] has also played a significant supporting role in this process.

The results resonate strongly with existing literature (Birthal *et al.,* 2008; Sharma, 2023), underscoring the strategic importance of crop diversification. This shift not only contributes to enhanced farm incomes but also acts as a crucial mechanism for risk mitigation and promoting long-term sustainability (Quiroz and Valdés, 1995). The increasing cultivation of high-value crops, particularly fruits and vegetables, is proving vital in bolstering farm earnings, generating employment opportunities, and strengthening the resilience of rural economies (Thapa *et al.,* 2017; Anuja *et al.,* 2020).

Diversification is propelled by a confluence of demand and supply-side factors. On the demand front, rising incomes, increasing urbanisation, and evolving consumer preferences are driving a dietary

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[1] The decline is not due to a reduction in agricultural GVA but rather a rapid expansion in industrial and service sector GVA (http://www.indiaenvironmentportal.org.in/files/file/winter_session_2023/Loksabha-Contribution%20of%20Agriculture%20in%20GDP.pdf).

[2] The gross cropped area of rice, coarse cereal, pulses, fruits and vegetables, oilseeds, and sugarcane was available till 2024-25, while that of wheat and tobacco was available till 2023-24. The aggregate gross cropped area was available till 2021-22. The latest data available for the gross value of output is available till 2022-23, therefore, the analysis is undertaken up to 2022-23.

[3] Cropping intensity denotes the degree to which cultivable land is engaged in crop production over a defined agricultural year. It serves as an indicator of the extent of utilisation of available arable land, reflecting the intensity of agricultural operations within a given period.

transition away from traditional cereals towards a greater consumption of fruits and vegetables (Singha *et al.,* 2014). This shift is corroborated by household consumption expenditure surveys, which indicate a declining demand for cereals alongside an increasing appetite for fruits. On the supply side, Agriculture Census data reveals that small and marginal farmers, who constitute the majority of Indian agriculture[4], are progressively allocating a larger share of their landholdings to horticulture, aligning with their labour-intensive farming practices.

Despite these encouraging trends, the study also highlights three critical areas that warrant attention: fluctuations in yields, inadequate and uneven post-harvest storage infrastructure, and heightened price volatility. These factors contribute to instability in farmers' incomes and often act as deterrents for smallholders from fully embracing high-value crops.

In this context, this study examines four important aspects:

(i) What are the primary sources of agricultural growth in India over the past three decades (1992-93 to 2022-23)?

(ii) What is the contribution of different crops to the overall growth of agriculture?

(iii) What are the implications of such growth on small farmers?

(iv) What are the challenges and policy considerations arising from this growth driven by diversification?

The subsequent sections of this article are structured as follows: Section II outlines the data and methodology, while empirical findings are presented in Section III. Section IV highlights challenges in horticulture, followed by concluding observations in Section V.

II. Data Source and Methodology

The study employs a growth decomposition methodology, complemented by an analysis of yield and price instability. The growth decomposition methodology of Minot (2003) facilitates a nuanced understanding of agricultural growth sources by incorporating physical factors - area, yield, and cropping pattern - and market-linked variables, namely, real prices and crop diversification. This approach enables the isolation of the contributions of area expansion, yield improvements, price effects, and crop diversification to overall agricultural growth. While this methodology provides a robust framework, it is important to acknowledge its drawbacks, including the limited ability to capture interaction effects between components and the absence of statistical inference due to its accounting-based structure (Sharma, 2023). Furthermore, the assumption of a uniform cost structure across crops, as highlighted by Minot (2003), may not always hold, potentially introducing aggregation bias.

In addition to the growth decomposition, the study assesses yield and price instability, given that instability is an inherent characteristic of agriculture, largely attributable to its susceptibility to weather-related shocks. Analysing agricultural instability is crucial as it has significant implications for both supply and demand dynamics. On the supply side, increased uncertainty can deter farmers from adopting new technologies or undertaking necessary investments. On the demand side, price volatility can disrupt consumption patterns and necessitate policy interventions focused on food security and market stabilisation (Anjum & Madhulika, 2018). Instability is commonly quantified using methods like the Cuddy-Della Valle Index (CDVI), Coefficient of Variation (CV), and standard deviation of first differences, which

[4] The average size of operational holdings has decreased from 2.28 hectares in 1970–71 to 1.08 hectares in 2015–16, indicating the increasing prominence of smallholder farming (PIB, 2020).

generate similar results (Huchet-Bourdon, 2011). This study employs the CDVI due to its ability to account for underlying linear trends often observed in prices (Huchet-Bourdon, 2011) and yield (Hazell, 1982).

II.1 Data sources

The analysis uses annual data for area, production, yield, and Index of Terms of Trade (ToT) between the agricultural and non-agricultural sectors (sourced from the Ministry of Agriculture and Farmer's Welfare) and value of output (obtained from National Account Statistics, Ministry of Statistics and Programme Implementation). To assess price dynamics, monthly price data are sourced from CMIE[5] for the period January 2002 to January 2025.

II.2 Methodology on the decomposition of sources of growth

This study employs the decomposition method pioneered by Minot (2003) and Joshi *et al.,* (2006) that breaks down the growth into area, prices, yield (or technology) and diversification. The real price is estimated by dividing the GVO by the quantity produced. Then, the prices were developed in real terms (2011-12 prices) using the Wholesale Price Index (WPI) released by the Ministry of Commerce and Industry.

Let A_i denote the area, Y_i is yield or the production per unit area, and P_i is the (real) price per unit of production under crop i. The gross revenue, R, from n crops can be expressed as:

$$R = \sum_{i=1}^{n} A_i P_i Y_i \quad \text{(I)}$$

Let a_i be the share of crop i in the total cropped area, *i.e.*, $a_i = A_i / \sum_i A_i$, the equation (I) can be rewritten as:

$$R = (\sum_{i=1}^{n} a_i P_i Y_i)(\sum_{i=1}^{n} A_i) \quad \text{(II)}$$

By taking the derivative of both sides of equation (II), we get

$$dR = (\sum_{i=1}^{n} a_i P_i Y_i)\boldsymbol{d}(\sum_{i=1}^{n} A_i) +$$

$$(\sum_{i=1}^{n} A_i)(\sum_{i=1}^{n} a_i P_i \boldsymbol{d}Y_i) + (\sum_{i=1}^{n} A_i)(\sum_{i=1}^{n} a_i Y_i \boldsymbol{d}P_i) +$$

$$(\sum_{i=1}^{n} A_i)(\sum_{i=1}^{n} Y_i P_i \boldsymbol{d}a_i) \quad \text{(III)}$$

The equation (III) is divided by dR and then multiplied by the growth rate of revenue (g_R) to get the relative contribution to growth.

$$g_R = \left[\frac{g_R}{dR}\right]\{\left(\sum_{i=1}^{n} a_i P_i Y_i\right)\boldsymbol{d}\left(\sum_{i=1}^{n} A_i\right) +$$

$$\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} a_i P_i \boldsymbol{d}Y_i\right) + \left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} a_i Y_i \boldsymbol{d}P_i\right)$$

$$+ \left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} Y_i P_i \boldsymbol{d}a_i\right)\}^{6} \quad \text{(IV)}$$

The right-hand side of equation (IV) tells the source of growth. The first, second, third and fourth term on the right-hand side represents the growth in the GVO due to the change in total cropped area (area effect), changes in yield (technology /yield effect), changes in real prices (price effect) and change in land use (diversification effect) respectively. A positive sign for the fourth term suggests a positive association between diversification and GVO, potentially reflecting a transition to more valuable crops.

The relative contributions of these growth drivers warrant careful consideration in the formulation of agricultural development policies. Agricultural growth driven by an expansion in the net sown area

[5] CMIE sources its data from the Agriculture Marketing Information Network (AGMARKNET) and National Commodity & Derivatives Exchange Limited (NCDEX). The data is sourced for a daily frequency for marketwise and variety-wise prices. The all-India estimates of overall prices across varieties and markets are computed as a simple average for the reference period by CMIE.

[6] The equation has ignored the interactive term. The interactive terms measure the change in output due to change in 2 or more inputs. The interactive terms are generally small and, therefore, ignored. However, the cumulative effect of the interactive term may be significant.

may not be sustainable in the long term, given the limited scope for further increases in cultivable land. In contrast, enhancing cropping intensity may offer a viable alternative, as it enables multiple uses of the same land parcel within a year. Growth arising from rising prices could be attributed to changes in pricing mechanisms or reductions in transportation costs; however, such price-induced growth is unlikely to be sustainable. Therefore, achieving long-term, sustainable agricultural growth necessitates a strategic focus on improving crop yields and diversifying production towards high-value crops (Birthal *et al.*, 2008).

The novelty of this study is to employ relative contribution rather than absolute contribution. This approach has been adopted primarily for its ability to capture the proportional impact of individual components on overall growth. For instance, in 1995-96, the aggregate GVO declined compared to the previous year (*i.e.*, $dR < 0$). During this period, the contribution of diversification (*i.e.*, the fourth term) was positive. Had the absolute contribution been considered, the contribution of diversification in that year would have appeared negative. Under the framework of relative contribution, however, the impact of diversification is positive, as the negative sign of dR is offset by the negative growth in GVO (*i.e.*, $g_R < 0$).

II.3 Instability Index

The CDVI Index is employed to assess the instability of time series data. It offers an advantage over the CV as it accounts for the underlying trend in the data. The CDVI achieves this by incorporating the adjusted R^2 from a semi-log linear trend model, thereby providing a more robust measure of variability in the presence of a deterministic trend (Cuddy and Della Valle, 1978).

$$\ln Y_i = \alpha + \beta t_i + \mu_i \quad \text{(V)}$$

Here, Y_i is the dependent variable specifying yield (kg/ha) or prices (₹/kg). The intercept term is denoted by α, while the slope term is denoted by β, and t_i is the time trend along with μ_i is the error term.

CDVI incorporates the adjusted R^2 of the equation (V) as shown below.

$$CV_t = CV \times \sqrt{(1 - R^2_{Adjusted})} \quad \text{(VI)}$$

$$CV = \sigma / x$$

Here, CV_t represents the coefficient of variation around the trend. In contrast, CV represents the coefficient of variation around the mean, and $R^2_{Adjusted}$ is the adjusted coefficient of determination from a time-trend regression. σ measures the standard deviation and x measures the mean.

III. Results and Discussion

III.1 Decoding Agriculture Growth Story

Table 1 dissects the drivers of India's agricultural growth, revealing the contribution of yield, diversification (both linked to government policies), area (evaluated by cropping intensity) and prices (gauged by the Index of Terms of Trade (ToT) between the agricultural and non-agricultural sectors). As farmers respond to relative prices rather than the price paid or received, the ToT was incorporated in MSP in 1980 (Dev and Rao, 2015). A ToT above 100 indicates favourable conditions, whereas a value below 100 suggests an adverse environment for farmers. With mounting pressure on agricultural land from industrialisation and urbanisation, expanding the net sown area faces inherent limits. Consequently, increased cropping intensity emerges as the key to maximising land utilisation and is used to measure area contribution.

Table 1: Contribution of Various Sources to Crop Sector Growth

Period	Area	Price	Yield	Diversification	Interaction
1992-93 to 2001-02	0.01	-0.79	1.72	0.76	0.26
2002-03 to 2011-12	0.83	-0.09	1.68	1.13	0.37
2012-13 to 2022-23	0.76	0.49	1.63	0.21	0.17
1992-93 to 2022-23	0.54	-0.11	1.67	0.68	0.26

Source: Author's calculation.

The initial decade (1992-93 to 2001-02) saw yield improvements (1.72 per cent) and diversification (0.76 per cent) fuel the majority of the growth (1.96 per cent). Despite a slight dip in net sown area (from 142.6 to 140.7 million hectares over the period), cropping intensity remained range-bound (130.1 per cent to 134.3 per cent over the period) (Chart 1.b). An unfavourable ToT likely contributed to negative price impacts (Chart 1.a). Notably, the "Golden Revolution" spurred significant gains in horticulture and apiculture, bolstering overall agricultural yield.

In the second period, yield (1.68 per cent), diversification (1.13 per cent), and area expansion (0.83 per cent) were the major contributors to the growth of 3.92 per cent. This period witnessed a rise in cropping intensity from 131.8 per cent (2002-03) to 138.9 per cent (2011-12) (chart 1.b).[7] ToT began to show signs of improvement during this period but continued to favour the non-agriculture sector (Chart 1.a). This partial recovery in ToT may account for the relatively improved, though still negative, contribution of prices to agricultural growth.

In the third period, all sources- area (0.76 per cent), prices (0.49 per cent), yield (1.63 per cent), and diversification (0.21 per cent)- contributed positively to the overall growth of 3.25 per cent. Cropping intensity saw a substantial jump from 139.15 per cent in 2012-13 to 155.4 per cent in 2021-22. During this

Chart 1: Terms of Trade and Cropping Intensity

Notes: 1. The Index of Terms of trade was present in two base years triennium ending (TE) 1990-91 and 2011-12. The TE 1990-91 was available from 1982-83 to 2006-07, while the TE 2011-12 was available from 2004-05 to 2022-23. To bring the data in common TE 2011-12, the data of TE 1990-91 was spliced with 0.80 (*i.e.*, the average of the common factor between two series).
2. Index value below 100 means the terms of trade are unfavourable to agriculture, while an index value above 100 means the terms of trade are favourable to agriculture.
3. Cropping Intensity measures the ratio of gross cropped area to net sown area. The higher the value of the cropping intensity, the amount of area is used in production.

Sources: Agricultural Statistics at a glance, various issues; and Author's calculation.

[7] The gross cropped area expanded significantly, from 173.9 million hectares in 2002–03 to 195.6 million hectares in 2011–12, whereas the net sown area increased modestly—from 132 million hectares to 140.8 million hectares over the same period.

period, ToT turned favourable, which may explain the positive contribution of prices to agricultural growth.

Over the period under consideration (1992-93 to 2022-23), the primary drivers of agricultural growth were yield improvements (1.67 per cent) and diversification (0.68 per cent), followed by area expansion (0.54 per cent). Yield gains likely stemmed from economic reforms, high-yielding seeds, irrigation focus, mechanisation, and fertiliser subsidies (Joshi, Gulati and Birthal, 2007). The analysis also indicates a rise in per-hectare production across all selected crops over the three-decade period. Diversification appears to be driven by multiple factors, including changes in dietary preferences among higher-income groups, policy initiatives such as the establishment of a dedicated Ministry of Food Processing Industries, and a shift in consumption patterns—from basic staple to high-value agricultural crop even in lower income brackets (Joshi, Gulati and Birthal, 2007). The rise in cropping intensity is likely linked to expanding irrigation, reducing reliance on rainfall.

A similar analysis was attempted to identify the sources of agricultural growth at the state level. However, due to the unavailability of Wholesale Price Index (WPI) data at the state level for the period under consideration, the study could not be pursued further. This study primarily examines diversification into horticulture, rather than focusing on yields, as the contribution of yield is well established (Sharma, 2023; Kumar, 2022).

III.2 Horticulture: The Bright Spot in Agricultural Growth

While horticulture encompasses a diverse range of crops such as fruits and vegetables, plantation crops, flowers, aromatic and medicinal plants, as well as spices and condiments, due to data limitations, the study focuses on fruits and vegetables (F&V). Table 2 highlights their consistently high growth rates across all three decades under review, underscoring their crucial role in driving agricultural performance. In 2022-23, F&V occupied a modest 5.77 per cent of the gross cropped area but impressively contributed 28.19 per cent to the GVO.

Table 2: Crop-Wise Contributions to Agriculture

Crop	Share in GCA (per cent)	Share in GVO (per cent)	Annual growth in value of output			Relative contribution to output growth		
	2021-22	2022-23	1992-93 to 2001-02	2002-03 to 2011-12	2012-13 to 2022-23	1992-93 to 2001-02	2002-03 to 2011-12	2012-13 to 2022-23
Rice	22.77	14.28	2.25	1.76	2.38	0.51	0.28	0.40
Wheat	15.88	8.90	2.93	2.83	1.48	0.41	0.36	0.16
Coarse Cereals	10.96	4.01	3.59	3.03	2.73	0.19	0.12	0.08
Pulses	13.64	5.17	2.27	3.11	4.84	0.13	0.16	0.35
Oilseeds	14.65	9.22	1.45	5.66	2.94	0.18	0.55	0.22
Sugarcane	2.96	5.03	5.46	1.11	0.53	0.43	0.05	0.13
F&V	5.77	28.19	5.86	4.33	3.84	1.45	1.33	1.30
Tobacco	0.18	0.32	-0.76	3.82	-2.32	-0.01	0.02	-0.02
Other crops	13.19	24.88	-	-	-	-	-	-
All crops	100	100	3.31	2.96	2.41	3.29	2.88	2.61

Notes: 1. All crops in the annual growth in the value of output consider growth of all the crops irrespective of those eight crops considered while all crops in the weighted contribution of growth shown only in eight crops considered.
2. The annual growth rate is estimated by taking the average of the annual growth rate in the period considered.
3. The relative contribution of output growth is measured by taking the aggregate value of GVO of the crops considered. Then, the average value of the change in GVO of each crop is divided by the aggregate value of GVO.

Sources: Agriculture Statistics at a Glance, 2023; and Author's calculation.

In Table 2, the annual growth in the value of output is estimated in two stages. In the first stage, the year-on-year (y-o-y) growth rate is calculated for each crop. In the second stage, the average growth rate for each crop is computed for the respective periods, such as 1992-93 to 2001-02. Based on this approach, fruits and vegetables exhibit the highest growth rate in all three periods under consideration. All other crops also show positive contributions to growth, except for tobacco.

The relative contribution of output growth is estimated in three stages in Table 2. In the first stage, the aggregate GVO is computed. In the second stage, the change in the GVO of each crop is expressed as a proportion of the aggregate GVO calculated in the first step. In the final stage, the average contribution of each crop to output growth is determined. From 1992-93 to 2022-23, the robust expansion of F&V output has been a significant tailwind for the agricultural sector, offsetting potential slowdowns elsewhere. In the initial period (1992-93 to 2001-02), F&V contributed a substantial 1.45 per cent to the overall 3.29 per cent growth. This strong contribution continued in the subsequent periods, accounting for 1.33 per cent of the 2.88 per cent growth (2002-03 to 2011-12) and 1.30 per cent of the 2.61 per cent growth (2012-13 to 2022-23). Without the contribution of F&V, agricultural growth would have been noticeably slower.

Underlying the strong performance of F&V is a gradual but distinct shift in Indian dietary patterns (Table 3). Data reveals a rising share of fruits in total food expenditure in both rural and urban areas- from 2 per cent in 2004-05 to 3.9 per cent in 2023-24. Vegetable consumption has remained largely stable in rural areas but has seen a slight uptick in urban centres. Conversely, the proportion of spending on cereals and pulses has been on a downward trend, signalling a broader diversification towards higher-value food items.

III.3 Cropping Patterns and Horticultural Diversification across Farm Sizes

An analysis of the cropping patterns of farmers[8], especially the land share dedicated to horticulture, is essential to assess whether small farmers are well-positioned to benefit from horticulture-led growth. As Chand (2017) highlighted, shifting one hectare of land from staple crops to high-value crops could enhance gross returns by ₹1,01,608. Encouragingly, small farmers already allocate a relatively larger portion of their land to horticulture compared to their larger counterparts (Table 4). In 2015-16, small farmers dedicated 6.08 per cent of their gross cropped area to these crops, *versus* 5.04

Table 3: Monthly Per Capita Consumption Expenditure

Item Group	Break-up of Monthly Per Capita Consumption Expenditure (per cent)									
	2004-05		2009-10		2011-12		2022-23		2023-24	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Cereals and cereals substitutes	18	10	13.8	8.2	10.8	6.7	4.9	3.6	5	3.8
Pulses and their Products	3	2	3.3	2.5	2.9	2	2	1.4	2	1.4
Vegetables	6	4	8.3	5.7	6.6	4.6	5.4	3.8	6	4.1
Fruits	2	2	2.4	3.2	2.8	3.4	3.7	3.8	3.9	3.9

Source: Household Consumption Expenditure Survey, Ministry of Statistics and Programme Implementation.

[8] Small farmers have landholding between 1-2 hectares while medium farmers have landholding between 4 -10 hectares. Large farmers have landholding more than 10 hectares.

Table 4: Cropping Pattern on Small *versus* Large Farms (Per cent of Gross Cropped Area)

Farm Size	Cereals	Pulses	Oilseeds	Sugarcane	Cotton	Fruits	Vegetables	S&C[9]	Others	Total
1995-96										
Small	64.42	8.9	10.07	2.6	3.64	1.59	2.53	1.24	7.55	100
Medium	58.12	10.47	13.27	2.45	6.07	1.28	1.58	1.21	7.14	100
Large	50.72	12.72	15.41	1.53	6.3	1.02	0.9	1.21	11.07	100
All	57.77	10.71	12.84	2.16	5.22	1.3	1.69	1.22	8.77	100
2015-16										
Small	62.28	8.90	11.19	2.68	5.50	1.76	3.03	1.29	3.37	100
Medium	52.64	11.92	15.57	2.69	7.68	1.69	1.97	1.66	4.18	100
Large	49.16	12.90	14.68	1.79	6.00	1.42	1.71	1.91	10.43	100
All	56.31	10.74	13.20	2.43	6.16	1.65	2.41	1.55	5.56	100

Sources: Agriculture Census, various issues.

per cent for large farmers and 5.32 per cent for medium farmers.

The increasing share of horticulture in the total cropped area across all farm sizes indicates a broader diversification trend. The sustained growth in cultivating fruits, vegetables, and spices & condiments reflects both the rising economic importance of smallholdings and growing consumer demand.

A closer look reveals that small farmers lean towards vegetable cultivation. These crops offer quicker returns, require less capital, and are more labour-intensive, aligning well with the resources of smallholders. In contrast, larger farmers tend to favour fruits and certain spices, which typically demand higher upfront investment and have longer maturity periods. For example, mango trees take 3-5 years to bear fruit, while onions can be harvested in about six months.

Table 5 reveals a compelling trend, where, in 1995-96, small farmers already dedicated the largest share of their land to horticulture, closely trailed by large farmers. By 2015-16, this lead widened as small farmers continued to expand their horticultural footprint. This increasing allocation underscores their strong capacity and willingness to diversify into these higher-value crops.

Tables 4 and 5 suggest that small farmers have increasingly diversified into horticulture, particularly vegetables, suggesting they may have benefited from this shift. However, despite these positive trends, several challenges persist, which are explored in the following section.

Table 5: Distribution of Area under Horticulture across Farm Categories (Per cent)

	Gross Cropped Area	Fruits	Vegetables	S&C
1995-96				
Small	38.6	47.2	57.6	39.1
Medium	23.9	23.4	22.4	23.7
Large	37.5	29.4	20.0	37.2
All	100.0	100.0	100.0	100.0
2000-01				
Small	41.1	47.3	56.7	39.8
Medium	24.0	24.1	18.8	23.4
Large	37.5	28.6	24.5	36.7
All	100.0	100.0	100.0	100.0
2015-16				
Small	48.3	51.6	60.7	40.2
Medium	23.4	23.9	19.2	24.9
Large	28.3	24.4	20.1	34.9
All	100.0	100.0	100.0	100.0

Sources: Agriculture Census, various issues.

[9] S&C refers to spices and condiments, which is included in horticulture.

IV. Challenges and Policy Focus[10]

While horticulture presents significant opportunities, this study now turns its attention to three key challenges that persist: the unpredictability of yields, insufficient storage infrastructure, and the volatility of prices. The study also discussed the government's policy responses aimed at mitigating these obstacles.

IV.1 Fluctuation in Yield

A significant challenge in horticulture is the inherent variability in yields (Annex Table 1). Fruit yields, in particular, show considerable fluctuation, as seen in crops like lemon, mosambi, oranges, grapes, litchi, mango, and sapota between 1992-93 and 2021-22. Notably, grape and sapota yield has declined over this period, highlighting the urgency for stabilisation. While vegetable yield has generally trended upwards (with exceptions like peas and tapioca), the overall growth in fruit and vegetable yield is largely propelled by vegetables. The underlying causes of this yield volatility warrant deeper investigation, which is beyond the scope of this study.

Table 6 highlights the instability in major fruit and vegetable yields as evidenced by CDVI. For vegetables, instability decreased between 2002-03 and 2011-12 (except for onions). Fruit yield instability, however, increased during this period (except for banana, oranges and papaya). The subsequent decade (2012-13 to 2021-22) saw reduced instability for fruits, while vegetables showed a mixed bag - increased instability for brinjal, tomato, and tapioca, but decreased instability for cabbage, peas, onion, and potato.

Table 6: Instability in the Yield of Major Fruits and Vegetables

Crops	1992-93 to 2001-02	2002-03 to 2011-12	2012-13 to 2021-22	1992-93 to 2021-22
Apple	0.08	0.15	0.12	0.14
Banana	0.06	0.06	0.03	0.06
Lemon	0.06	0.17	0.05	0.12
Mosambi	0.13	0.21	0.07	0.23
Orange	0.18	0.15	0.05	0.19
Grapes	0.13	0.24	0.01	0.20
Guava	0.04	0.05	0.04	0.08
Mango	0.05	0.10	0.06	0.15
Papaya	0.12	0.05	0.04	0.10
Total Fruits	**0.06**	**0.06**	**0.05**	**0.10**
Brinjal	0.03	0.01	0.03	0.03
Cabbage	0.09	0.02	0.01	0.08
Cauliflower	0.12	0.02	0.02	0.07
Peas	0.14	0.04	0.03	0.13
Tomato	0.05	0.03	0.06	0.06
Onion	0.06	0.10	0.06	0.10
Potato	0.08	0.07	0.05	0.07
Tapioca	0.05	0.03	0.21	0.15
Total Vegetables	**0.04**	**0.02**	**0.02**	**0.03**

Sources: Department of Agriculture and Farmers Welfare, Ministry of Agriculture & Farmers Welfare; and Author's calculation.

To address yield fluctuations in horticulture, the government has launched the Mission for Integrated Development of Horticulture (MIDH). This umbrella scheme encompasses key programmes, including the National Horticulture Mission and the Horticulture Mission for North East and Himalayan States, which focus on providing high-quality planting material[11] and tissue culture[12] units, expanding cultivation areas, and promoting advanced horticulture technology.[13] Additionally, the Horticulture Cluster Development

[10] In this subsection, the study focuses on individual crops. As per the first advance estimates 2024-25, banana (37.7 million MT), guava (5.4 million MT), mango (22.7 million MT), papaya (5.4 million MT), grapes (4.1 million MT), apple (2.7 million MT), lemon (3.8 million MT), mosambi (3.9 million MT), and orange (6.1 million MT) contributed to 81 per cent to total fruits production (113.2 million MT). Brinjal (13 million MT), cabbage (10.4 million MT), cauliflower (9.9 million MT), peas (6.8 million MT), tomato (21.5 million MT), onion (28.9 million MT), potato (59.6 million MT), and tapioca (6.3 million MT) contributed to 70 per cent of total vegetables production (214.5 million MT). These crops are considered in this section.

[11] Quality Planting Material may be defined as 'the production of uniform, healthy, disease-free planting material raised through seed or vegetative methods with an overall goal to raise the physiological and phytosanitary quality of the plant available to stakeholders to increase productivity' (ICAR-CAFRI, 2019).

[12] Tissue culture (TC) is the cultivation of plant cells, tissues, or organs on specially formulated nutrient media. Under the right conditions, an entire plant can be regenerated from a single cell (ISAAA).

[13] https://www.myscheme.gov.in/schemes/midh

(HCD) program, launched in 2021, aims to enhance global competitiveness by creating market-driven development across 55 identified clusters.[14] This is complemented by a strong emphasis on research and development, evidenced by the growing number of establishments of dedicated institutes, research centres and directorates.

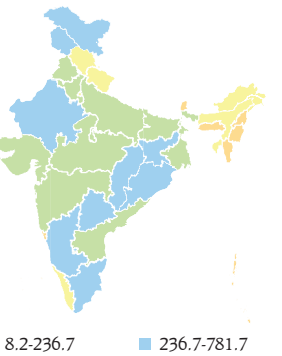
IV.2 Lack of Post-Harvest Storage Capacity

India grapples with substantial post-harvest losses, estimated at around ₹1.5 trillion annually (Gulati *et al.*, 2024), with fruits and vegetables bearing the brunt due to inadequate cold storage (Negi and Anand, 2017). Effectively addressing these post-harvest losses necessitates a dual approach encompassing the expansion of cold chain infrastructure and the reinforcement of the food processing sector to prolong the shelf life of agricultural commodities.

As of 2022, India's cold storage capacity stood at 38.2 million metric tonnes (MT), exhibiting significant regional concentration, with Uttar Pradesh (38.9 per cent), West Bengal (15.6 per cent), Gujarat (10.2 per cent), and Punjab (6.4 per cent) accounting for 71 per cent of the total. Chart 2, employing quartile distribution, vividly illustrates these regional disparities. Strikingly, approximately 75 per cent of existing cold storage is dedicated to potatoes, highlighting both the limited capacity for other perishables and the prominence of potatoes in Indian consumption (Tiwari, 2021). Furthermore, the location of these facilities near production hubs underscores their reliance on efficient transportation networks. The development of versatile, multi-commodity cold storage faces technical hurdles in maintaining diverse temperature and humidity requirements.

To boost post-harvest infrastructure and improve the agricultural supply chain, the government has launched several key initiatives. Agriculture Infrastructure Fund (AIF), established in 2020, has already sanctioned over 48,000 storage projects, adding a capacity of 94 million tonnes.[15] Reinforcing this thrust, the Union Budget 2025–26 announced an air cargo facility to support horticultural exports. Complementary schemes such as the Pradhan Mantri Formalisation of Micro Food Processing Enterprises (PMFME), and the Mega Food Park initiative aim to improve processing, storage, branding, and value addition. While broad-based in scope, these interventions are expected to yield substantial spillover benefits for the horticulture sector.

Chart 2: State-wise Cold Storage Capacity (in thousand metric tons)



Notes: 1. The number of cold storages in Ladakh is considered the same as that in Jammu and Kashmir.
2. The states are classified based on the number of cold storages. States belonging to the first quartile have storage capacity of less than 8.2 thousand metric tons. The second quartile has a capacity between 8.2 to 236.7 thousand metric tons. The third and fourth quarters have a capacity between 236.7 to 781.7 thousand metric tons and more than 781.7 metric tons, respectively.
Source: Handbook of Statistics on Indian States, RBI.

IV.3 Volatility in Prices[16]

Prices are the lifeline for farmers, steering their production and investment decisions. However, price volatility acts as a significant disruptor, influencing crop choices, input application, and technology adoption, while also injecting uncertainty across the agricultural value chain (Sharma *et al.*, 2024).

[14] https://nhb.gov.in/CDPMap.aspx

[15] https://pib.gov.in/PressNoteDetails.aspx?NoteId=152061&ModuleId=3&reg=3&lang=1

[16] Given data availability, the analysis in this subsection spans from 2002-03 to 2021-22, with rice and wheat included to provide a comparative perspective *vis-a-vis* horticulture crop.

Table 7 unveils interesting trends in the price instability of major fruits and vegetables. Notably, fruit price volatility eased during 2012-13 to 2022-23 compared to the preceding decade. Conversely, vegetable price volatility generally intensified over the same period, except for peas and cauliflower.

The stability and upward trajectory of rice and wheat prices, as depicted in Chart 3, offer a compelling contrast. Given the Food Corporation of India's (FCI) primary procurement focus on these cereals, the combination of assured buyers, lower price fluctuations, and rising price trends likely contributes to farmers' persistent preference for these crops over the more volatile fruits and vegetables.

Table 7: Instability in the Prices of Major Fruits and Vegetables

Crops		2002-03 to 2011-12	2012-13 to 2022-23	2002-03 to 2022-23
Cereals	Rice	0.08	0.04	0.08
	Wheat	0.06	0.05	0.06
Fruits	Bananas	0.15	0.09	0.15
	Guavas	0.16	0.05	0.1
	Mango	0.09	0.06	0.07
	Papaya	0.11	0.05	0.08
	Grapes	0.09	0.04	0.05
	Apple	0.13	0.10	0.14
	Lemons	0.26	0.13	0.19
	Mousambi	0.13	0.05	0.09
	Oranges	0.15	0.06	0.11
	Watermelon	0.09	0.04	0.07
Vegetables	Brinjal	0.05	0.06	0.08
	Onion	0.18	0.28	0.27
	Potato	0.25	0.34	0.34
	Tomato	0.07	0.16	0.16
	Topioca	0.14	0.16	0.18
	Cabbage	0.09	0.10	0.12
	Cauliflower	0.06	0.05	0.09
	Peas	0.11	0.09	0.09

Sources: CMIE and Author's calculation.

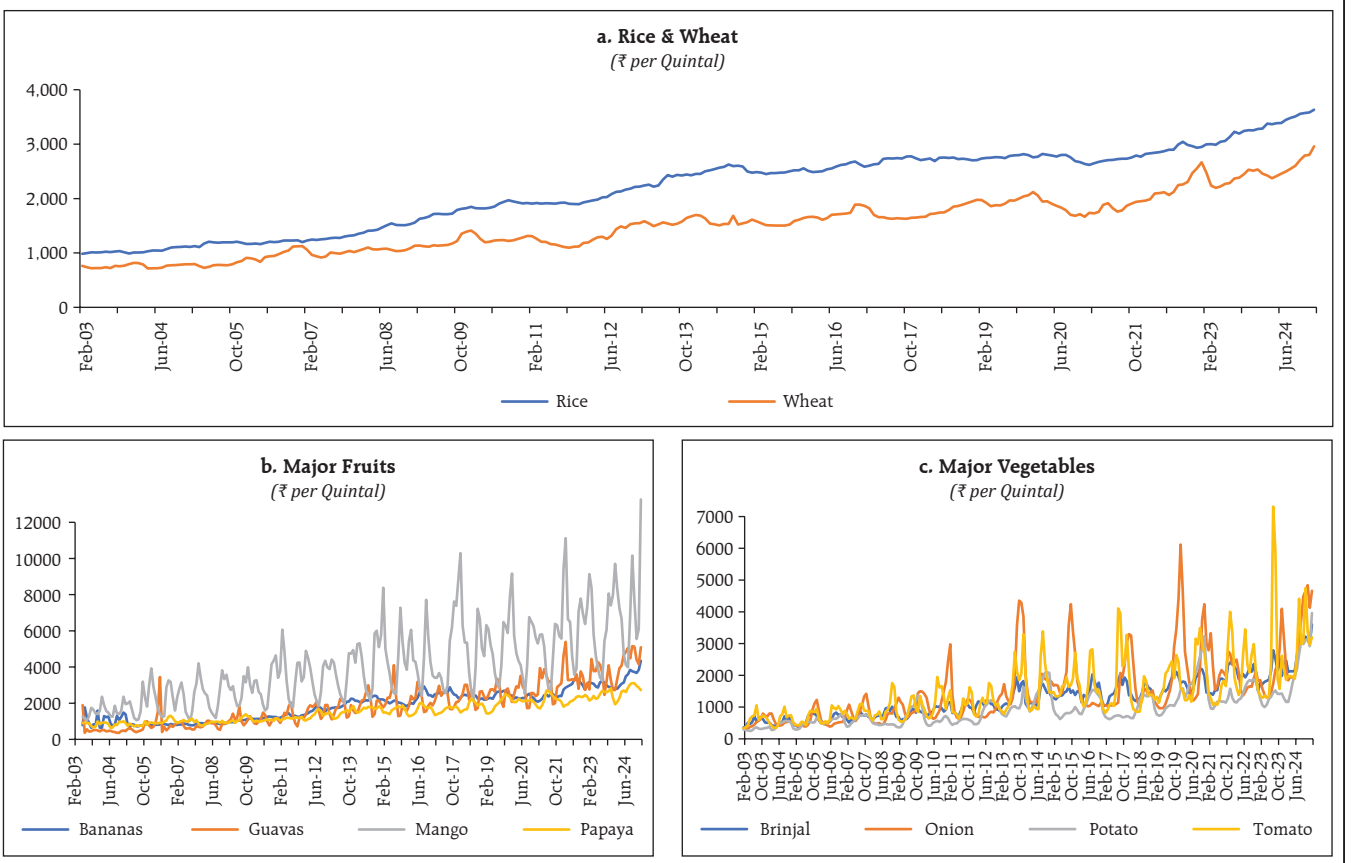
Recognising the challenges posed by price volatility in horticulture, the Government of India launched 'Operation Greens'. Initially focused on Tomato, Onion, and Potato (TOP), this scheme, announced in the Union Budget 2018-19, aims to shield farmers from distress sales and curtail post-harvest losses. Its scope was subsequently broadened in 2021-22 to encompass all fruits and vegetables under the umbrella of TOTAL.

V. Conclusion

Over the past three decades (1992-93 to 2022-23), agricultural growth has been significantly propelled by yield (or technological) improvement, diversification, and increased cropping intensity. Notably, the shift towards horticulture has been a key growth engine, particularly benefiting small farmers. However, the sector still grapples with yield and price volatility, exacerbated by insufficient cold storage. Government initiatives like the NHM and HCD target yield stability, while the AIF and PMFME aim to fortify cold chain infrastructure and supply chain efficiency- crucial steps forward.

Going forward, establishing stronger linkages between farmers and export markets, as well as urban consumers, will be critical for accelerating agricultural growth and development. Additionally, intercropping of horticultural and non-horticultural crops holds promise for improving yields, enhancing soil health, and augmenting farmer incomes. Strengthening agricultural research to develop technologies that address emerging challenges—such as climate change and pest management—while also improving productivity, remains imperative. The growth of agro-processing industries can unlock the potential for higher export growth, reduce post-harvest losses, and generate employment opportunities in the rural economy.

Chart 3: Prices of Various Commodities



Note: As rice and wheat are one of the most produced crops in India, it's price is used as a standard to compare with major fruits and vegetables.
Source: CMIE.

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Annex:

Table 1: Average Yields of Various Horticulture Crops

(Metric Tonnes/Hectares)

Horticulture	1992-93 to 2001-02	2002-03 to 2011-12	2012-13 to 2021-22	1992-93 to 2021-22
Total Fruits	**11.5**	**11**	**14.2**	**12.5**
Apple	5.5	7.5	7.7	7
Banana	30.1	33.6	35.6	33.7
Lemon*	8.9	8.8	10.7	9.7
Mosambi*	11.9	10.1	15.5	12.7
Oranges*	8.7	7.7	12	10.1
Grapes	22.2	19.9	21.6	21.2
Guava	11.1	11.2	15	12.9
Litchi	6.8	6.7	7	6.9
Mango	7.5	6.4	8.5	7.5
Papaya	24.3	35.8	41.5	36
Pineapple	14.6	15.3	16.5	15.6
Pomegranate	-	7	11.1	10.1
Sapota	12	8.5	11.1	10
Total Vegetables	**14**	**15.9**	**17.8**	**16.3**
Brinjal*	15.6	17	17.9	17
Cabbage	20.1	22	22.7	21.9
Cauliflower	16.5	18.5	19.4	18.4
Okra	9.7	10.6	11.9	10.9
Peas	9.1	8.1	9.9	9.2
Tomato	15.6	18.4	23.8	20.2
Onion	10.6	14.8	16.9	15.2
Potato	17.3	19.4	23	20.4
Sweet Potato	8.5	9	10.9	9.4
Tapioca	24.9	32.7	30.2	29.2

Notes: 1. *: Data available from 1993-94 onwards.
2. -: Not Available.
3. Here, yield is calculated by taking the average production divided by the average area under cultivation during the period. This study has deliberately not compared the yield of a specific year as that year's yield may be impacted by exogenous factors such as weather events, pests, and diseases, *etc.*
4. Yellow colour indicates the fall in yield, while green colour indicates the rise in yield. The yield in 2002-03 to 2011-12 is compared with that from 1992-93 to 2001-02, while the yield from 2012-13 to 2021-22 is compared with 2002-03 to 2011-12. The overall yield from 1992-93 to 2021-22 is compared with 1992-93 to 2001-02.

Sources: Department of Agriculture and Farmers Welfare, Ministry of Agriculture & Farmers Welfare; and Author's calculation.