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Shift in cropping pattern in India: The diversification trend & its determinants

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Abstract

The study examined how cropping patterns changed in Indian agriculture between 1993-1994 and 2022-2023. Using secondary data on gross cropped area and employing diversity indices (Simpson Index, Entropy Index, Herfindahl-Hirschman Index), and ridge regression techniques, the study examines both the patterns and determinants of diversification. The findings show that while fine-cereals like rice and wheat continue to dominate the gross cultivated area, the proportion of coarse cereals has significantly decreased with respect to gross cropped area under cereals. A noticeable transition towards high-value and market-oriented agricultural production is evident from the concurrent growth in the area under fruits, vegetables, spices, fibers, and commercial crops like cotton and sugarcane. These trends are confirmed by the diversification indices. As crop diversity expanded over time, the EI in gross cropped area increased from 1.51 to 1.67 and the SID in gross cropped area increased from 0.66 to 0.71 during 1993-94 to 2022-23. On the other hand, the HHI decreased from 0.34 to 0.29, suggesting that a small number of important crops are no longer as dominant and concentrated. Diversification, however, was still limited within food crops, with SID values of 0.64 in 1993-1994 and 0.62 in 2022-2023. The analysis of determinants by ridge regression showed that rainfall (-0.14) and traditional crop profitability (-0.17) had a negative impact on diversification decisions, while rural literacy (0.86) and urban population growth (0.66) were the main positive factors of diversification towards horticulture.

Keywords: Diversification, Simpson's index, Herfindahl-Hirschman index, Entropy index, determinants

Introduction

Agriculture has long been the backbone of India's economy, providing livelihoods to over 50% of the population and contributing significantly to the nation's GDP. However, the sector faces numerous challenges, including climate change, declining soil fertility, water scarcity, and fluctuating market prices. In response, agricultural diversification has emerged as a critical strategy to enhance farm income, reduce risks, and promote sustainable farming practices. Diversification in agriculture refers to shifting from traditional cropping patterns to varied agricultural activities. It involves moving from staple food crops to horticulture, livestock, fisheries, and agroforestry. According to Vyas (1996) ^[34], diversification strategies in agriculture can take several forms, which involves moving away from conventional farming practices toward non-agricultural activities, replacing low-profit crops or enterprises with those that offer higher returns, and utilizing available resources across different but complementary areas to enhance overall productivity and resilience. Athawale *et al.* (2024) ^[2] stated that enhancing crop diversification strategy fosters economic progress and contributes significantly to the sustainable management of natural resources, emphasizing its dual importance in promoting economic growth and ensuring environmental sustainability. Diversification seeks to optimize the use of water, land, and other resources, ensuring their efficient management through ecosystem regulation and maintenance. It also contributes to enhancing biodiversity, which in turn supports the overall advancement

of a nation's agricultural sector (Hufnagel *et al.*, 2020) ^[17]. In recent years, diversification has drawn significant attention in India due to agricultural growth becoming more or less stagnant, an incomplete transformation of the sector, and persistently low productivity. Crop diversification also serves as an effective strategy to enhance agricultural output across a variety of conditions (Banerjee & Banerjee, 2015) ^[3].

The rationale for diversification is multifaceted: it mitigates production and market risks, responds to changing consumer demand patterns, enhances employment opportunities, conserves ecological resources, and fosters more inclusive and sustainable rural development. The diversification in agricultural sector can be viewed in three ways: i) horizontal, ii) vertical, and iii) allied activities. The horizontal diversification means the growing multiple crops i.e., adding more crops to the existing cropping base. The vertical diversification means of adding additional activities like milling, processing and refining, etc. Diversification towards allied activities mean adding activities like livestock, fisheries, and agroforestry. In India, the process of diversification has been driven by several interconnected factors. On the demand side, rising incomes, urbanization, and changing dietary preferences have spurred a shift in food consumption towards high-value and nutrient-rich commodities (Birthal *et al.* 2020, Joshi *et al.* 2004) ^[10, 21]. On the supply side, advancements in infrastructure, technological innovations, market liberalization, and targeted policy interventions have enabled farmers to access

new markets and production technologies (Joshi *et al.* 2004)^[21]. Moreover, Sharma (2005)^[32] stated that diversification has been seen as a vital mechanism to alleviate the challenges associated with small and fragmented landholdings, water scarcity, and vulnerability to climatic stresses.

Importantly, agricultural diversification is not a uniform process across regions. Its patterns and drivers vary considerably depending on agro-climatic conditions, market access, infrastructure availability, and socio-economic characteristics of farming communities (Athawale *et al.* 2024)^[2]. In resource-poor or rainfed areas, diversification often serves as a risk management strategy, favoring resilient, low-input crops (BIRTHAL *et al.* 2020)^[10]. Trends vary across regions due to differences in agro-climatic conditions, resource availability, and market access. For example, Punjab and Haryana are dominated by the rice-wheat cropping system due to irrigation facilities, while Maharashtra and Gujarat have seen a shift towards cotton, sugarcane, and horticultural crops. In southern India, there has been significant growth in fruits, vegetables, and spices, while coastal regions have expanded their fisheries and aquaculture sectors. For instance, the share of marine fish in total fish production declined from 75 per cent in 1960-61 to 54 per cent in 2013-14, while inland fisheries increased from 25 per cent to 46 per cent during the same period (Joshi *et al.* 2004)^[21]. In contrast, regions with better irrigation, road connectivity, and market access tend to witness diversification towards more remunerative high-value crops (Chand *et al.* 2016, Joshi *et al.* 2004)^[11, 21]. Several factors drive agricultural diversification in India. Market forces, such as changing consumer preferences and export opportunities, play a crucial role. For example, the demand for basmati rice, spices, and horticultural products has encouraged farmers to shift from traditional crops. Technological advancements, including the adoption of high-yielding varieties, irrigation technologies, and mechanization, have enabled farmers to diversify into high-value crops. For instance, the introduction of short-duration rice varieties has allowed farmers in West Bengal to grow wheat as a second crop (BIRTHAL & Hazrana, 2019)^[9]. Government policies promoting crop diversification, such as subsidies for horticulture and oilseeds, have also been instrumental. However, policies favoring rice and wheat through minimum support prices (MSP) have hindered diversification in some regions. Climate change, with its erratic rainfall, rising temperatures, and frequent droughts, has further forced farmers to adopt climate-resilient crops and practices. For example, farmers in rainfed regions are shifting from water-intensive crops like rice to millets and pulses.

Despite its benefits, agricultural diversification faces several challenges. Market access and infrastructure remain significant barriers. Poor infrastructure, lack of storage facilities, and inadequate transportation networks hinder the marketing of high-value crops. For instance, perishable products like fruits and vegetables often suffer post-harvest losses due to inadequate cold storage facilities. Risk aversion among farmers is another challenge. Farmers are often reluctant to shift from traditional crops due to uncertainty in returns and lack of knowledge about new crops and technologies. Policy barriers, such as subsidies

and support systems favoring rice and wheat, discourage diversification. For example, the MSP system has led to overproduction of these crops, leaving little incentive for farmers to diversify. Resource constraints, including limited access to irrigation, credit, and technology, further restrict diversification, especially for small and marginal farmers. Given these dynamic transformations, understanding the concept, rationale, and evolving patterns of agricultural diversification in India is crucial for designing informed and region-specific policies. Such policies can enhance agricultural resilience, improve farm profitability, and contribute significantly to the broader goals of rural development and national food security.

Data Sources & Methodology

The present study focuses on India as the study area, encompassing its diverse agro-climatic zones and heterogeneous farming systems. India, with its wide range of ecological conditions, socio-economic structures, and cropping patterns, offers an ideal setting to examine agricultural diversification comprehensively.

The time period studied for the analysis is spread over three decades, from the agricultural year 1993-94 to 2022-23. This timeframe captures crucial structural changes in Indian agriculture, including post-liberalization reforms, technological advancements, globalization impacts, and recent policy initiatives promoting diversification and sustainability.

Data Sources

The present study on agricultural diversification in India relies primarily on secondary data collected from a range of authentic sources, including publications of the Ministry of Agriculture and Farmers Welfare, Government of India, Directorate of Economics and Statistics, and various reports of the National Sample Survey Office (NSSO). Time-series data on cropped area under major crops have been utilized to analyze the extent and pattern of diversification. Data related to area, production & productivity of field crops was obtained from Agricultural Statistics at A Glance while for horticultural crops, it was obtained from FAOSTAT as well as Agricultural Statistics at A Glance. Value of outputs was obtained from National Accounts Statistics.

Analytical Framework

To measure the extent of diversification, three widely accepted indices have been employed in the present study: Simpson's Index of Diversity (SID), Entropy Index (EI), and Herfindahl-Hirschman Index (HHI). Each index captures different dimensions of crop diversification, providing a comprehensive view of the cropping pattern dynamics.

1. Simpson's Index of Diversity (SID)

The Simpson's Index is one of the most commonly used indices for analyzing diversification level in agriculture. It considers both, the variety and even distribution of crops. The index is defined as:

$$SID = 1 - \sum_{i=1}^n P_i^2$$

where, SID is Simpson's Index of Diversity

P_i is share of i^{th} activity in total area/gross value, etc.
The numeric value of this index ranges between 0 (Zero) and 1. A value closer to 1 indicates a higher level of diversification, while a value approaching 0 (Zero) suggests a greater concentration towards a few crops.

2. Herfindahl-Hirschman Index (HHI)

The Herfindahl-Hirschman Index, originally developed in industrial organization studies, has been adapted in agricultural economics to study concentration in cropping patterns. It is computed as:

$$HHI = \sum_{i=1}^n P_i^2$$

where, HHI is Herfindahl-Hirschman Index of Diversity

P_i is share of i^{th} activity in total area/gross value, etc.

The numeric value of this index also varies between 0 (Zero) and 1. A lower HHI indicates more diversification, while a higher value reflects more concentration on a few crops. It is noteworthy that HHI is inversely related to diversification, and therefore, $(1 - HHI)$ is often used as a simple measure of diversification.

3. Entropy Index (EI)

The Entropy Index provides another perspective on diversification by measuring the distribution of area among various crops. It is calculated as:

$$EI = - \sum_{i=1}^n P_i \ln P_i$$

where, EI is Entropy Index

P_i is share of i^{th} activity in total area/gross value, etc.

$\ln$ is natural logarithm

Higher values of the Entropy Index indicate a more diversified cropping structure. Unlike SID, the Entropy Index is sensitive to the presence of minor crops and changes in cropping patterns over time.

Determinants of diversification

To identify the key factors influencing the diversification towards horticultural crops in India, an econometric analysis was carried out using a ridge regression model. The functional form of the model is specified as:

$$y = f(\text{irrigation, landholding, electricity, demand, rainfall, profitability, rural literacy, urban population})$$

where, y = Farm area devoted to horticultural activities (as a percentage of gross cropped area).

Variables Specification

- Dependent Variable:
 - a. Area under horticultural crops: Measure of the proportion of the total agricultural land used for horticultural crops.
- Independent Variables:
 - a. Irrigation: The share of land irrigated (gross) in relation to the total cropped area.
 - b. Landholding: Share of marginal and small landholdings as a percentage of total landholdings.

- c. Electricity: Electricity consumption in agriculture as a percentage of total electricity consumption.
- d. Rainfall: Annual average rainfall (in millimeters).
- e. Demand: Per capita income as a proxy for consumer demand for high-value crops.
- f. Profitability: The Producer Price Index for horticultural crops (adjusted based on a base year).
- g. Rural Literacy: Rural literacy rate (in percentage).
- h. Urban Population: The percentage of the population living in urban areas as a proxy for market expansion.

Analytical Techniques

Given the potential multicollinearity among independent variables – a common issue in economic models dealing with socio-economic and infrastructural factors – ridge regression was adopted. Ridge regression is a regularization technique that addresses multicollinearity by introducing a penalty term to the least squares estimation, thereby stabilizing coefficient estimates without significantly compromising model fit. The regression analysis was conducted using R software, leveraging its advanced capabilities for regularization techniques and diagnostic testing.

Results and Discussion

The present section discusses the empirical findings related to the extent and patterns of agricultural diversification in India over the period 1993-94 to 2022-23. Using the computed values of Simpson's Index of Diversity, Entropy Index, and Herfindahl-Hirschman Index, the analysis highlights the temporal changes, regional variations, and structural shifts in the cropping patterns. Further, the underlying drivers influencing diversification trends are examined, offering critical insights into the evolving dynamics of Indian agriculture in the context of economic growth, technological advancements, and policy reforms.

Trends in Agricultural Diversification in India (1993-94 to 2022-23)

The table 1 shows the distribution of gross cropped area among different crop groups in India. There have been notable changes between 1993-94 and 2022-23, reflecting broader trends of agricultural diversification. Fine cereals have maintained a consistently high share throughout the period, fluctuating between 37 per cent and 39 per cent, with a slight upward trend to 39.35 per cent in 2022-23, indicating their continued importance in the cropping pattern. In contrast, the area under coarse millets has shown a steady decline, dropping sharply from 16.45 per cent to 10.24 per cent, suggesting a shift away from traditionally rainfed crops, likely due to changing food consumption patterns and reduced profitability. The share of pulses remained relatively stable, with some fluctuations, peaking at 14.02 per cent in 2017-18 before slightly declining to 12.55 per cent by 2022-2023. This pattern reflects targeted policy interventions such as the National Food Security Mission.

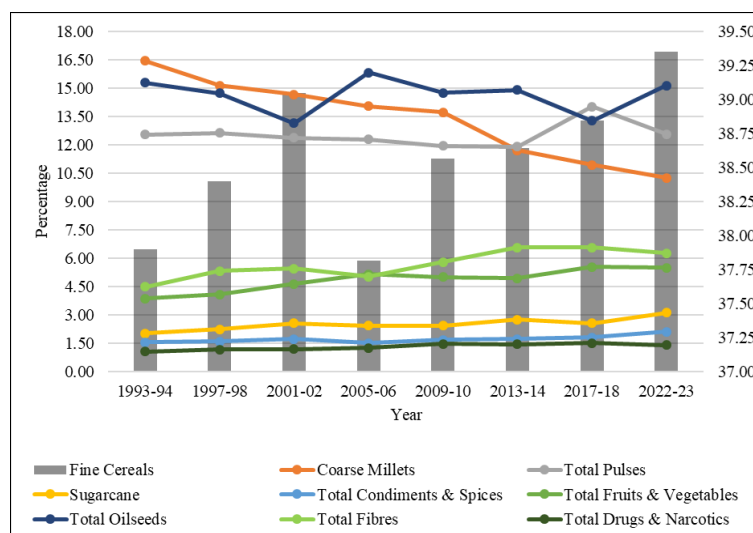


Fig 1: Graphical representation of share of different crop groups in gross cropped area

The area under sugarcane expanded modestly over the period, increasing from 2.01 per cent to 3.10 per cent, likely

driven by its industrial demand and profitability. Similarly, condiments and spices

Table 1: Share of different crop groups in gross cropped area (GCA) during 1993-94 to 2022-23 in India

Year	Fine Cereals	Coarse Millets	Total Pulses	Sugarcane	Total Condiments & Spices	Total Fruits & Vegetables	Total Oilseeds	Total Fibres	Total Drugs & Narcotics	Fodder Crops
1993-94	37.90	16.45	12.55	2.01	1.53	3.86	15.29	4.48	1.04	4.43
1997-98	38.40	15.14	12.63	2.23	1.57	4.06	14.72	5.30	1.15	4.31
2001-02	39.04	14.66	12.37	2.55	1.71	4.62	13.13	5.44	1.18	4.63
2005-06	37.82	14.04	12.28	2.41	1.50	5.15	15.83	5.02	1.23	4.18
2009-10	38.56	13.71	11.93	2.41	1.66	4.99	14.75	5.79	1.46	3.92
2013-14	38.64	11.69	11.90	2.75	1.71	4.92	14.90	6.56	1.43	4.75
2017-18	38.84	10.94	14.02	2.54	1.80	5.52	13.27	6.55	1.50	4.37
2022-23	39.35	10.24	12.55	3.10	2.10	5.48	15.13	6.26	1.39	3.50

exhibited a gradual increase in their share, rising from 1.53 per cent to 2.10 per cent, pointing to growing domestic and export demand. Fruits and vegetables expanded notably, from 3.86 per cent to 5.48 per cent, highlighting a trend towards high-value horticultural crops supported by improved irrigation facilities and changing dietary preferences. The area under oilseeds remained relatively stable, oscillating between 13 per cent and 15 per cent, indicating consistent domestic demand for edible oils despite growing import pressures. Fibre crops, particularly cotton, saw an increase in share from 4.48 per cent to 6.26 per cent, a trend likely fueled by technological advancements such as Bt cotton adoption and rising export opportunities. Minor crops such as drugs and narcotics maintained a low but slightly increasing share, reflecting niche market growth. Meanwhile, fodder crops experienced a gradual decline from 4.43 per cent to 3.50 per cent. Overall, the changes in cropping pattern demonstrate a gradual shift towards more remunerative and market-responsive crops, underscoring the twin forces of market dynamics and policy initiatives that are reshaping Indian agriculture.

The table 2 shows the growth rates of gross cropped area under different crop groups during the period from 1993-94

to 2022-23, which reveals a significant temporal and sectoral variations. For fine cereals, the gross cropped area grew moderately at 0.57 per cent per annum during Period-I (1993-94 to 2002-03), slowing down to 0.28 per cent in Period-II (2003-04 to 2012-13) and 0.33 per cent in Period-III (2013-14 to 2022-23), resulting in a marginal overall growth of 0.11 per cent across the study period. In contrast, coarse millets experienced a consistent decline across all periods, with growth rates of -1.30, -2.01, and -1.73 per cent in Periods 1, 2, and 3, respectively, culminating in an overall negative growth of -1.64 per cent. The total pulses category initially showed negative growth in Periods 1 (-0.64%) and 2 (-0.80%) but rebounded significantly with a positive growth rate of 1.28 per cent in Period-III, leading to a modest overall increase of 0.07 per cent. Sugarcane cultivation expanded steadily, recording growth rates of 2.52, 1.90, and 1.02 per cent across the three periods, although the pace of expansion slowed over time, resulting in an overall growth rate of 0.78 per cent as given in table 2. This growth is fueled by the rising demand for sugar and ethanol, coupled with favorable support prices and irrigation infrastructure improvements in key sugarcane-producing states like Uttar Pradesh, Maharashtra, and Karnataka.

Table 2: Growth rates in gross cropped area under different crop groups during different periods in India

Parameters	Period-I	Period-II	Period-III	Overall
Fine Cereals	0.57	0.28	0.33	0.11
Coarse Millets	-1.30	-2.01	-1.73	-1.64
Total Pulses	-0.64	-0.8	1.28	0.07
Sugarcane	2.52	1.90	1.02	0.78
Total Condiments & Spices	1.50	1.48	1.81	1.17
Total Fruits & Vegetables	2.81	-0.26	1.14	1.25
Total Oilseeds	-1.56	-0.21	0.21	-0.06
Total Fibres	1.04	3.66	-0.62	1.09
Total Drugs & Narcotics	2.06	2.65	-0.69	1.29
Fodder Crops	-0.72	-0.84	-4.97	-0.47

Period-I: 1993-94 to 2002-03; Period-II: 2003-04 to 2012-13; Period-III: 2013-14 to 2023-24; Overall: 1993-94 to 2023-24; Values in percentages

The area under total condiments and spices exhibited relatively stable and high growth, with rates of 1.50, 1.48, and 1.81 per cent across the respective periods, leading to an overall growth of 1.17 per cent. Similarly, the total fruits and vegetables group saw strong growth during Period-I (2.81%), a marginal contraction in Period-II (-0.26%), and a recovery in Period-III (1.14%), resulting in an overall growth of 1.25 per cent.

Total oilseeds showed a declining trend initially (-1.56% in Period-I and -0.21% in Period-II), followed by a slight recovery of 0.21 per cent during Period-III; however, the overall growth remained slightly negative at -0.06 per cent. Policies like the National Mission on Oilseeds and Oil Palm (NMOOP) have supported oilseed cultivation, particularly for mustard, soybean, and groundnut. Despite the increasing domestic demand for edible oils, the expansion of oilseed cultivation has been constrained by yield stagnation and competition from other crops. In the fibre crops group, growth accelerated sharply to 3.66 per cent in Period-II, after recording 1.04 per cent in Period-I, but turned negative at -0.62 per cent in Period-III, leading to an overall growth

of 1.09 per cent. The area under total drugs and narcotics grew at 2.06 per cent during Period-I and peaked at 2.65 per cent in Period-II, but declined by -0.69 per cent during Period-III, maintaining an overall positive growth rate of 1.29 per cent. Conversely, fodder crops consistently contracted across all periods, with growth rates of -0.72, -0.84, and -4.97 per cent, respectively, resulting in an overall decline of -0.47 per cent over the entire period.

The trends in the percentage share of gross cropped area under different food crop groups from 1993-94 to 2022-23 reveal important structural changes within Indian agriculture as shown in table 3. Fine cereals (mainly rice and wheat) consistently occupied the largest share among food crops, rising gradually from 53.09 per cent in 1993-94 to 56.42 per cent in 2022-23. The share peaked around 2014-15 at 57.33 per cent, reflecting the continued policy focus on staple grain production for food security. Coarse millets, on the other hand, witnessed a steady decline over time, from 22.03 per cent in 1993-94 to just 14.47 per cent by 2022-23 – indicating a shift away from traditional, climate-resilient grains toward finer cereals.

Table 3: Percentage share of different crop groups in gross cropped area under food crops in India

Year	Fine Cereals	Coarse Millets	Total Pulses	Total Condiments & Spices	Total Fruits & Vegetables	Other Food Crops
1993-94	53.09	22.03	17.34	2.12	5.33	0.09
1997-98	54.03	20.46	17.57	2.19	5.64	0.10
2001-02	54.36	19.74	17.07	2.36	6.38	0.09
2005-06	53.75	19.45	17.34	2.12	7.26	0.07
2009-10	54.66	18.98	16.81	2.34	7.03	0.18
2013-14	56.29	16.67	17.25	2.48	7.13	0.18
2017-18	54.72	15.14	19.67	2.52	7.75	0.19
2022-23	56.42	14.47	17.94	3.00	7.84	0.34

The area under total pulses showed fluctuations, moving from 17.34 per cent in 1993-94 to 17.94 per cent in 2022-23, with notable peaks in 2017-18 (19.67%) and 2021-22 (19.17%). This reflects renewed policy initiatives in recent years to promote pulse cultivation, given concerns around protein security. The share of condiments and spices increased moderately, from 2.12 per cent in 1993-94 to 3 per cent in 2022-23, suggesting gradual diversification towards high-value crops. Similarly, the area under fruits

and vegetables rose from 5.33 per cent to 7.84 per cent over the period, underlining the growing importance of horticultural crops in response to changing consumer preferences and better market opportunities. The observations are in line with other studies (Chand *et al.* 2016) ^[11]. The category of other food crops remained negligible throughout the period but showed a slight increase in the later years, reaching 0.34 per cent in 2022-23.

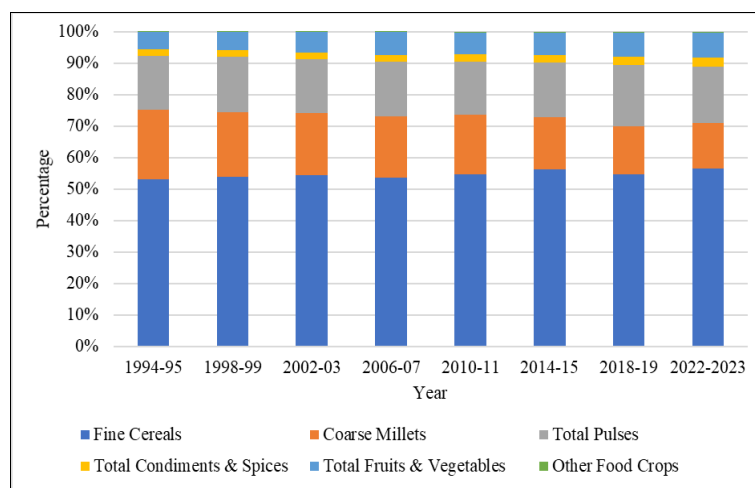


Fig 2: Percentage of Different Crop Groups in Food Crops' Gross Cropped Area

Overall, while fine-cereals maintained dominance, there was visible diversification within the food crops group, with increased emphasis on pulses, fruits, vegetables, and spices, particularly after the mid-2000s. However, the declining share of coarse millets points to a narrowing of biodiversity within food grains, which has implications for sustainability and nutrition security.

Temporal Analysis of Diversification Indices

The diversification indices based on gross cropped area reveal a consistent trend towards increased crop diversification in Indian agriculture during the period 1993-94 to 2022-23 as shown in table 4. The Simpson Index of Diversity (SID) rose steadily from 0.66 in 1993-94 to 0.71 in 2022-2023, indicating a gradual broadening of the cropping pattern and reduced dominance of any single crop group. Similarly, the Entropy Index (EI) increased from

1.51 to 1.67 over the same period, reflecting a more even and equitable distribution of the gross cropped area among multiple crops. The EI exhibited a noticeable acceleration post-2010-11, suggesting a more pronounced shift towards diversification in recent years.

Table 4: Different diversity indices in gross cropped area under crops in India

Year	SID	EI	HHI
1993-94	0.66	1.51	0.34
1997-98	0.67	1.55	0.33
2001-02	0.67	1.57	0.33
2005-06	0.68	1.58	0.32
2009-10	0.68	1.60	0.32
2013-14	0.70	1.65	0.30
2017-18	0.70	1.65	0.30
2022-23	0.71	1.67	0.29

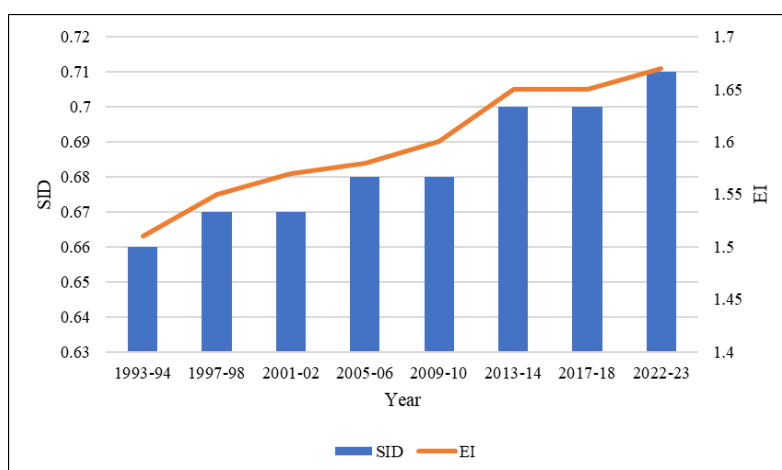


Fig 3: Diversity Indices in Gross Cropped Area under Crops in India

Conversely, the Herfindahl-Hirschman Index (HHI) declined from 0.34 to 0.29 between 1993-94 and 2022-23, further corroborating the trend of declining crop concentration. The consistent fall in HHI values, particularly after 2010, points towards a reduction in the area share of dominant crops and greater inclusion of high-value and niche crops. The simultaneous movement in SID, EI, and HHI collectively confirms that agricultural production has

transitioned towards a more diversified structure, likely driven by factors such as policy interventions, market-led diversification, technological advancements, and the need to mitigate climatic and price risks.

These findings underscore the structural transformation within Indian agriculture, highlighting a shift from traditional cereal-dominated systems towards more market-oriented and resilient cropping patterns.

Diversification in food and non-food crops group

The diversification indices for gross cropped area under food and non-food crop groups from 1993-94 to 2022-23 indicate a relatively stable pattern with only marginal changes over the period as shown in table 5.

Table 5: Different diversity indices in gross cropped area under food & non-food crop groups in India

Year	SID	EI	HHI
1993-94	0.38	0.57	0.62
1997-98	0.38	0.57	0.62
2001-02	0.37	0.56	0.63
2005-06	0.39	0.58	0.61
2009-10	0.39	0.58	0.61
2013-14	0.41	0.60	0.59
2017-18	0.39	0.58	0.61
2022-23	0.39	0.58	0.61

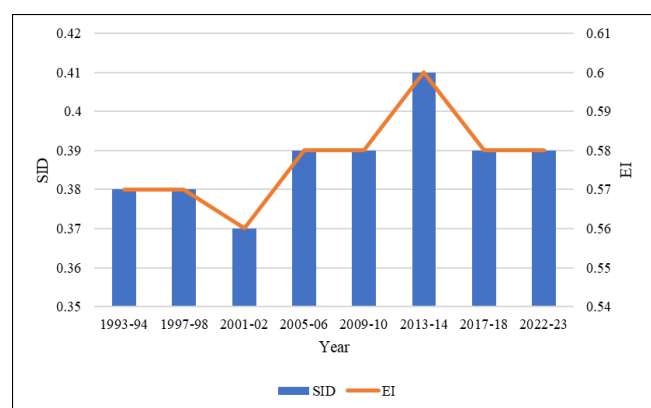


Fig 4: Diversity Indices in Gross Cropped Area under Food & Non-Food Crop Groups

The Simpson Index of Diversity (SID) remained within a narrow range, oscillating between 0.36 and 0.41. It showed a slight improvement from 0.38 in 1993-94 to 0.39 in 2022-23, suggesting only a limited increase in the diversification between food and non-food crop groups. A modest rise in SID during 2011-16 indicates a minor phase of diversification towards non-food crops. The Entropy Index (EI) also exhibited minimal variation, maintaining a range between 0.55 and 0.60 across the study period. EI values improved slightly post-2010, reaching 0.60 in 2012-16, reflecting a minor shift towards a more even distribution between food and non-food crops. However, the limited magnitude of change suggests that food crops continued to dominate the cropping structure despite some diversification into non-food categories.

Conversely, the Herfindahl-Hirschman Index (HHI) remained relatively high throughout the period, fluctuating between 0.59 and 0.64. The consistently high HHI values imply that the concentration of gross cropped area under a few major crop groups (predominantly food crops) remained significant. Although there was a slight decline in HHI around 2012-16, indicating a small reduction in concentration, the overall pattern points towards a sustained dominance of food crops over non-food crops in the agricultural landscape. These findings are in line with other studies (Barman *et al.* 2022; Joshi *et al.* 2004) [5, 21].

Diversification within the food crops group

The analysis of diversity indices, as shown in table 6 in the gross cropped area under food crop groups from 1993-94 to 2022-23 reveals a largely stable but subtly shifting pattern. The Simpson Index of Diversity (SID) fluctuated narrowly between 0.61 and 0.65 over the three decades, indicating a moderately high and relatively consistent level of crop diversification within the food crops category. Initially, SID values were around 0.64 (1993-94), but slight dips were observed during 2014-15 and 2020-21, where the index dropped to 0.61, pointing towards a minor concentration in cropping patterns during these periods towards fine cereals and fruits and vegetables.

The Entropy Index (EI), another measure of diversity, showed similar stability, ranging from 1.20 to 1.25. A marginal increase in EI was observed in the early 2000s, peaking at 1.25 during 2003-04, suggesting a brief phase of relatively greater diversification within food crops. The Herfindahl-Hirschman Index (HHI), which measures concentration (with higher values implying greater concentration), generally ranged from 0.35 to 0.39. The HHI tended to rise slightly in years where SID and EI dipped, as seen in 2014-15 and 2020-21, reinforcing the observation of marginal increases in crop concentration during those years.

Table 6: Different diversity indices in gross cropped area under food crops group in India

Year	SID	EI	HHI
1993-94	0.64	1.22	0.36
1997-98	0.63	1.22	0.37
2001-02	0.63	1.22	0.37
2005-06	0.64	1.23	0.36
2009-10	0.63	1.23	0.37
2013-14	0.62	1.22	0.38
2017-18	0.63	1.24	0.37
2022-23	0.62	1.23	0.38

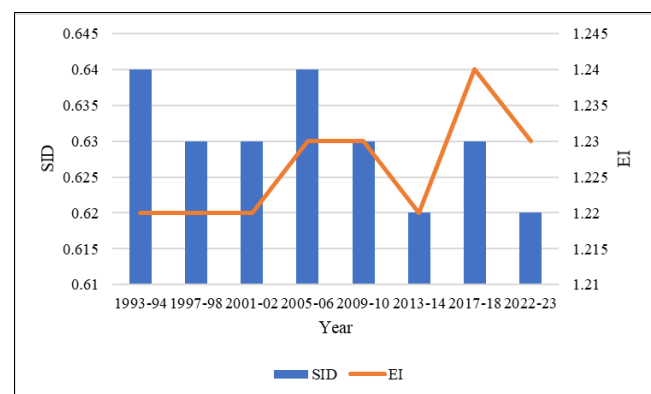


Fig 5: Diversity Indices in Gross Cropped Area Under Food Crops Group in India

Overall, while the food crop group maintained a fairly diverse structure over the study period, minor episodes of concentration can be detected, likely reflecting shifts in policy priorities, market dynamics, or climatic factors influencing farmers' crop choices. Nevertheless, the changes were not drastic, suggesting a strong inherent stability in the cropping pattern of food crops in India over the last three decades.

Shifts in Cropping Patterns

The period from 1993-94 to 2022-23 witnessed significant realignments in India's cropping patterns, driven by economic, policy, and environmental factors. One of the most prominent shifts has been the gradual movement away from cereals, particularly coarse cereals, toward fruits, vegetables, and commercial crops.

Decline in Cereals, Particularly Coarse Millets: The gross cropped area under coarse cereals declined steadily across all periods, recording an overall negative growth rate of -1.64 per cent. This decline can be attributed to multiple factors like constant consumer preferences towards fine cereals like rice and wheat, enhanced government procurement and minimum support price (MSP) systems favoring fine cereals, and the perception of higher economic returns from other crops. In contrast, fine cereals like rice and wheat maintained their dominance but experienced stagnating or marginal growth in area.

Rise in Fruits and Vegetables: Fruits and vegetables exhibited robust growth, with an overall annual growth rate of 1.25 per cent. Several factors underpinned this expansion; rising urbanization, increasing per capita income, and growing awareness among consumers, all of which led to a surge in demand for horticultural products. Policy support through missions like the National Horticulture Mission (NHM), improved irrigation facilities, and better access to markets and cold storage infrastructure also encouraged farmers to diversify into high-value horticulture crops.

Increase in Area Under Commercial Crops: The area under commercial crops such as sugarcane, cotton (fibres), condiments and spices, and drugs and narcotics expanded significantly. Sugarcane maintained positive growth across all periods, driven by strong industrial demand (sugar and bioethanol production) and assured returns. Cotton area grew impressively during the mid-2000s, boosted by technological innovations like Bt cotton adoption, rising textile industry demand, and favorable price movements. Similarly, spices and condiments benefited from export market expansion, and drugs and narcotics crops attracted farmers due to their high profitability despite regulatory controls.

One of the most prominent trends in Indian agriculture is the shift from traditional cereals like rice and wheat to high-value crops such as fruits, vegetables, oilseeds, and cash crops like cotton and sugarcane. For instance, in Haryana, the area under paddy increased by 398%, while rapeseed and mustard saw a 419% rise from 1970-71 to 2013-14 (Bhatia *et al.*, 2020) [8]. Similarly, in Maharashtra, farmers are increasingly moving towards horticultural crops like grapes and mangoes, which offer higher returns. This shift is driven by changing consumer preferences, rising demand for high-value products, and export opportunities. However, this trend has also led to a decline in the cultivation of coarse cereals like sorghum (jowar), pearl millet (bajra), and pulses, which are losing ground due to low profitability and limited market demand. In Haryana, the area under gram declined by 92%, maize by 90%, and bajra by 48% during the same period (Bhatia *et al.*, 2020) [8]. Another significant trend is the growth of the livestock and fisheries sectors,

which have emerged as important components of agricultural diversification. In Haryana, the dairy sector has grown significantly, contributing to farm income and employment. Similarly, in coastal states like Andhra Pradesh and Tamil Nadu, inland fisheries and aquaculture have gained prominence, replacing traditional crop-based farming systems (Joshi *et al.*, 2004) [21].

Factors Influencing Agricultural Diversification

The results of the ridge regression analysis, as shown in table 7 highlight several significant determinants of diversification into horticulture. The model intercept is estimated at -3.45, indicating the baseline level of horticultural diversification when all explanatory variables are at their reference points. Among the independent variables, the log of gross irrigated area (log_girri) exhibits a positive coefficient of 0.17, suggesting that greater irrigation availability is associated with increased diversification into horticulture (Pavithra & Gaddi, 2022; Sahu, 2021) [28]. Similarly, access to electricity (log_elec) shows a positive but relatively modest coefficient of 0.05, implying that improved rural electrification supports diversification, likely by facilitating irrigation facilities. Conversely, the log of rainfall (log_rain) displays a negative coefficient of -0.14, indicating that areas with higher rainfall are somewhat less likely to diversify into horticulture, potentially because rain-fed regions may favor traditional field crops over intensive horticultural production. Household income (log_income) shows a very small positive coefficient (0.01), suggesting a limited direct impact of income on horticultural diversification. Interestingly, the log of agricultural profitability (log_profit) carries a negative coefficient (-0.17), implying that higher profitability from conventional crops might discourage shifts towards horticulture, where returns could be more uncertain or require higher initial investments. These findings present a deviation from other studies (Barman *et al.* 2022; Basavaraj *et al.* 2016) [5, 6].

Table 7: Determinants of diversification in horticulture

Independent Variable	Coefficient
(Intercept)	-3.45
log_girri	0.17
log_elec	0.05
log_rain	-0.14
log_income	0.01
log_profit	-0.17
log_urbanpop	0.66
log_RuralLit	0.86
lambda: 0.001	

Dependent Variable: Area under horticultural crops

Independent Variables:

gIrriArea: Gross Irrigated Area as percent of total;

SmallLand: Marginal + Small Landholding as percent of Total;

ElecCons: Electricity Consumption in Agriculture as percent of total;

Rain: Annual rainfall;

Income (Per Capita Income);

Profit: Producer price index for horticulture;

Rural Literacy; Urban Population

Among the demographic factors, urbanization (log_urbanpop) emerges as an important driver, with a strong positive coefficient of 0.66, reflecting the growing demand for horticultural products in urban markets. Additionally, rural literacy (log_RuralLit) has the highest positive coefficient at 0.86, indicating that higher levels of rural education are strongly associated with greater diversification into horticulture. This underscores the role of human capital in enabling farmers to adopt more knowledge-intensive and market-oriented agricultural practices and the findings are in concurrence with studies by Athawale *et al.* (2024)^[2] and Daya *et al.* (2022)^[12]. The ridge penalty parameter (λ) is set at 0.001, minimizing multicollinearity effects while maintaining coefficient interpretability.

Conclusions

The observed shifts in cropping patterns have significant implications for agricultural sustainability, food security, and rural livelihoods. The decline in the area under coarse millets, despite their ecological resilience and nutritional value, raises concerns regarding agro-biodiversity and climate adaptability. Conversely, the expansion of pulses, horticulture, and fibre crops suggests a positive transition towards more market-responsive and income-enhancing agricultural systems. The increasing diversification into high-value crops such as fruits, vegetables, and spices indicate farmers' adaptation to changing consumer demands and urban market dynamics. However, the continued dominance of fine cereals within the food crops category reflects higher profitability and less risk involved due to procurement by public agencies at Minimum Support Price (MSP). Moving forward, special attention needs to be given for cultivation of food crops to ensure food and nutritional security coupled with adoption of climate-resilient cropping systems for attaining inclusive growth in agricultural production. The production of coarse cereals should be incentivised by ensuring procurement at MSP. There is a need for value chain development in horticulture, and sustainable intensification strategies will be critical to ensuring that the benefits of diversification are widespread and resilient to future challenges.

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