

RESEARCH PAPER

Growth and Stability of Indian Cereal Production under the National Food Security Mission: Insights from Hazell Decomposition and Instability Analysis

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ABSTRACT

India's increasing population and changing dietary needs have made food security a top priority. To address this challenge, the government launched the National Food Security Mission (NFSM) in 2007, aiming to enhance the production of essential crops and ensure sustainable agricultural growth. Measuring the trends of growth and variability in agricultural production is crucial to understanding how outputs have changed over time and evaluating the effectiveness of such initiatives. This study examined the effect that NFSM has on the growth and variability of rice, wheat, pulses, and coarse cereals (including millets, maize, sorghum, and barley) using data obtained from the Food and Agriculture Organization database. The study period is divided into pre-NFSM (1993-2007) and post-NFSM (2008-2022) for rice, wheat and pulses cereals, and pre-NFSM (2007-2014) and post-NFSM (2015-2022) for coarse cereals. Three analytical methods, i.e., Compound Annual Growth Rate analysis, Cuddy Vella Instability Index, and Hazell decomposition analysis were used to estimate crop production growth, instability and the influencing factors of fluctuations in crop production. The findings indicate that NFSM has significantly increased the growth of production of rice, wheat and particularly pulses. Following the implementation of the NFSM, the overall growth rate of area for coarse cereals decreased, except maize. However, the growth rate of production and yield increases, except for barley. Furthermore, the predominant factors influencing the total change in average production are changes in mean yield and mean area. Only sorghum's production was primarily influenced by an increase in cultivation area. The production of variance for all crops is influenced mainly by yield variance and area-yield covariance. However, only barley and millet are primarily affected by area variance and covariance. Thus, the significant increase in production, yield, and stability demonstrates the mission's food security achievement. To maintain and enhance the success of NFSM, it is crucial to prioritize ongoing technical progress, implement steps to increase resilience and adopt inclusive policies.

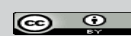
HIGHLIGHTS

- ❶ The findings indicate that NFSM has significantly increased the growth of production of rice, wheat and particularly pulses. Following the implementation of the NFSM, the overall growth rate of area for coarse cereals decreased, except maize, and the growth rate of production and yield increases, except for barley.
- ❷ Predominant factors influencing the total change in average production are changes in mean yield and mean area. Only sorghum's production was primarily influenced by an increase in cultivation area.
- ❸ The production of variance for all crops is influenced mainly by yield variance and area-yield covariance. However, only barley and millet are primarily affected by area variance and covariance.

Keywords: Food security, NFSM, growth analysis, Hazell decomposition analysis

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Food security is regarded as a fundamental pillar of economic growth and social stability, as it reduces the risk of social instability and mitigates inequality within communities (Pourreza *et al.* 2018; Oladipo & Oyinloye, 2022). According to (FAO 2023), food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Ensuring food security is also a central objective of the Sustainable Development Goals, particularly Goal 2, which seeks to eliminate hunger and malnutrition by 2030.

Globally, cereals play a crucial role in ensuring food security, providing about 50 percent of the nutritional energy and protein required for billions of people (Muitire *et al.* 2021). They also help stabilize economies, mitigate risks of food shortages, and support rural livelihoods through extensive employment. However, food security faces significant challenges due to overpopulation and competition for resources (Singh *et al.* 2017). By 2050, the global population is expected to reach 9.1 billion, requiring a significant increase in cereal production, estimated at around 3 billion tons (Batten, 2019). This global challenge is particularly acute in India, which has the world's largest population, making the need for food security highly important. With the population estimated at 1.43 billion in 2023 and projected to reach 1.7 billion by 2060 (Bhagat & Rajput, 2023), the growing demand for food combined with shrinking arable land due to urbanization places immense pressure on the agricultural sector (Kimani, 2021). As the demand for food increases alongside a shrinking availability of arable land, the pressure on agricultural productivity intensifies. This situation makes it critical to not only maintain but also enhance the stability of agricultural production, particularly for staple cereals such as rice, wheat, pulses and coarse cereal.

Agricultural production stability is a essential of both food security and economic resilience (García-Díez *et al.* 2021), particularly in a country like India, where a large segment of the population depends on cereals such as rice, wheat, and pulses not only as dietary staples but also as a primary source of rural income and employment (Ajatasatru *et al.* 2024; Sachdev & Misra, 2023). However, fluctuations in

their production driven by variability in yield or the area under cultivation can disrupt the food supply chain and undermine economic stability in agrarian regions (Arata *et al.* 2020). Despite their importance, India's cereal yields remain considerably lower than those in other major producing countries; for example, rice and wheat yields are approximately half of those in China and France, respectively. This persistent yield gap points to underutilized capacity for improving agricultural practices. Enhancing productivity and stabilizing cereal production are thus critical not only for meeting the country's rising food demand but also for strengthening the economic foundations of rural livelihoods.

These pressures underscore the importance of understanding how past agricultural strategies such as the Green Revolution attempted to enhance food security and why a more inclusive approach like the NFSM became necessary. India adopted the Green Revolution strategy in the late 1960s, which significantly increased rice and wheat production. This shift transformed the country from a food-deficit nation into a net food grain exporter (Prasad, 2019). However, these gains were uneven—undernutrition persisted, and the focus on rice and wheat led to the neglect of pulses and coarse cereals, which are crucial for nutritional security and climate resilience (Gangwar *et al.* 2014; Stepha, 2022; Yadav & Anand, 2019). Moreover, studies found mixed effects on production stability, with some regions experiencing reduced yield variability and others facing increased fluctuations (Hazell, 1984; Larson *et al.* 2004). In response to these limitations, the Government of India launched the National Food Security Mission (NFSM) in 2007–08. Unlike the earlier approach, NFSM adopted a more inclusive strategy to improve the productivity of rice, wheat, pulses, and coarse cereals by bridging yield gaps through modern agronomic practices and input support.

In comparison to the extensive body of research on the Green Revolution, relatively fewer studies have examined the impact of the National Food Security Mission (NFSM), particularly at the national level. Most existing evaluations remain fragmented focusing on specific crops, such as rice or pulses, or limited to individual states thus limiting broader insights into NFSM's effectiveness across India's cereal economy. For instance, Chatterjee and Gir

(2010) emphasized the need for increased production of rice, wheat, and pulses, while highlighting financial and implementation constraints. Thomas *et al.* (2013) reported reduced yield instability for pulses in key growing states, and Shah (2014) found that NFSM interventions improved pulse cultivation and farm incomes in Maharashtra. Similarly, Babu *et al.* (2016) noted gains in paddy productivity, income, and employment in Karnataka, while Sivagnanam *et al.* (2019) observed enhanced cereal output in Tamil Nadu due to better input availability.

Despite these contributions, critical gaps remain. Most studies do not account for coarse cereals, which are essential for nutritional security and climate resilience. Furthermore, evaluations have often been disaggregated by crop or region, without assessing the overall impact on cereal production stability. Additionally, prior research rarely employs decomposition frameworks, such as Hazell's (1982) method, which enables disaggregated analysis of output growth into area, yield, and interaction components. This methodological gap constrains our understanding of the key drivers of production change under NFSM.

This study addresses these limitations by evaluating NFSM's impact on cereal production growth and stability at the national level. Specifically, it investigates: (i) how cereal production trends have evolved since NFSM's implementation; (ii) whether the mission has contributed to production stability across major cereals; and (iii) which components—yield, area, or their covariance—drive variability under the NFSM framework. These insights are intended to inform evidence-based improvements in NFSM design, supporting national food security and economic resilience amid growing population pressure and resource constraints.

MATERIALS AND METHODS

Data

This study utilizes time series data on harvested area, production, and yield at the national level for rice, wheat, pulses, and coarse cereals from 1993 to 2022. The data were sourced from the Food and Agriculture Organization website. In 2007, the government implemented the National Food Security Mission (NFSM) to enhance food production and achieve food security. The NFSM,

initiated in 2007-08, primarily focused on three major crops: rice, wheat, and pulses. From 2014-15 onward, the government included coarse cereals such as millets (bajra, jowar, barley, ragi, and maize) under NFSM. To assess the effect of the NFSM on the growth and instability of rice, wheat, pulses and coarse cereal production and yield, we divided the data of each studied variable (i.e., harvested area, production, and yield) into two periods: (1) pre-NFSM and (2) post-NFSM. For rice, wheat, and pulses, the pre-NFSM period is from 1993 to 2007, and the post-NFSM period is from 2008 to 2022, with each period consisting of 15 years. The coarse cereal period is divided into two distinct timeframes. However, we divided it differently due to coarse cereals, including in the NFSM starting in 2014-15. For the analysis of Hazell decomposition, the number of years in period-1 and period-2 will be equal. Thus, the periods for coarse cereal are pre-NFSM (2007-2014) and post-NFSM (2015-2022). The main consideration behind dividing the total period into two sub-periods was to observe changes in growth, instability, and the factors contributing to the total output.

METHODOLOGY

Compound Annual Growth Rate

Compound and linear growth rates are two distinct methods to measure the growth rate. Linear growth is limited when comparing the growth of two periods (Dandekar, 1981). Thus, CAGR estimates the growth rate of Area, Production and yield.

In order to estimate the compound growth rates, the log-linear functional form was used. The formula for calculating CAGR is:

$$Y_t = ab^t u_t \quad \dots(1)$$

where,

y_t = harvested area (ha)/production (t)/ yield (t/ha)

a = intercept

b^t = The regression coefficient $(1 + r)$ represent the instantaneous relative change in Y for a given absolute change in an explanatory variable, where r is the growth rate, $\ln$ is the natural logarithm

u_t = is the error term.

The CAGR was calculated by taking the logarithmic form of Eq. (1) and applying the following formula:

$$\ln Y = \ln a + t (\ln b) + u_t \quad \dots(2)$$

The compound annual growth rate (r) of harvested area (ha), production (t), and yield (t/ha) in percentage was obtained by using the function:

$$CAGR(r) = (\text{antilog } b -) * 100 \quad \dots(3)$$

The student's t-test assessed the significance of the regression coefficient.

Instability Index

Cuddy Vella instability index has been used to estimate the instability in harvested area, production, and yield. It is more accurate to compare to the coefficient of variation because it reduces the overestimated variability (Cuddy & Vella, 1978) In the past, various Researchers have used the Cuddy-Vella instability index to measure variability in agriculture production (Ayele *et al.* 2021; Joshi *et al.* 2021; Sethi *et al.* 2022).

$$CDVI = CV * \sqrt{(1 - R^2adj)} \quad \dots(4)$$

Hazell Decomposition Analysis

Decomposition models play a crucial role in understanding the impact of different factors on crop production (Blomqvist *et al.* 2020; Jainuddin *et al.* 2019; Mondal *et al.* 2014). It helps in segregating the contributions of various components like area and yield to the overall output growth. Additionally, it aims to identify and quantify the sources of variation in crop production across time. There are various methods related to decomposition. So, in this study, Hazell decomposition analysis is used to identify and measure component elements in the change of crop production (Hazell, 1982; Hazell, 1984).

Model

Firstly, yield and area data on different crops were detrended using linear regression of the following form:

$$X_t = a + b_t + e_t \quad \dots(5)$$

X_t is the dependent variable (harvested area, production or yield), a is the intercept, b_t is the parameter to be estimated, t is the time in years, and e_t is the residual with mean zero and variance σ^2 .

The residuals were centered on mean area and mean yield. The detrended data for the yield and area were obtained by using the following formula:

$$X_t = e_t + \bar{X} \quad \dots(6)$$

The detrended data on production were obtained by multiplying the detrended area by the de-trended yield.

Average production for the entire period $E(Q)$, So average production $E(Q)$ can be expressed as:

$$E(Q) = \bar{A}\bar{Y} + Cov(A, Y) \quad \dots(7)$$

Where, let A and Y denote the mean area and yield, $Cov(A, Y)$ Covariance of area and yield.

A variance of production can be expressed as the following

$$V(Q) = A^2V(Y) + \bar{Y}^2V(A) + 2\bar{A}\bar{Y}Cov(A, Y) - Cov(A, Y)^2 + R \quad \dots(8)$$

Where R denotes the residual term and is expected to be small.

Now, for the base period, average production is $E(Q_0) = \bar{A}_0\bar{Y}_0 + Cov(A_0, Y_0)$ and for terminal period, it is,

$$E(Q_t) = \bar{A}_t\bar{Y}_t + Cov(A_t, Y_t) \quad \dots(9)$$

Since $\bar{A}_t = \bar{A}_0 + \Delta\bar{A}_t$ and $\bar{Y}_t = \bar{Y}_0 + \Delta\bar{Y}_t$ therefore, average production in the terminal year can be expressed as:

$$E(Q_t) = (\bar{A}_0 + \Delta\bar{A}_t)(\bar{Y}_0 + \Delta\bar{Y}_t) + Cov(A_t, Y_t) + \Delta Cov(A_t, Y_t) \quad \dots(10)$$

Now change in average production can be denoted as $\Delta E(Q_t) = E(Q_t) - E(Q_0)$. This expression, after appropriate substitution, finally turns out to be

$$E(Q_t) = \bar{A}_0\Delta\bar{Y}_0 + \Delta\bar{A}_t\bar{Y}_t + \Delta Cov(A_t, Y_t) \quad \dots(11)$$

Component of Change in an average production and variance in output can decompose into several components, and the whole scheme of decomposition is presented in the table below:

Table 1: Components of Change in Average Production

Sources of Change	Symbol	Component of change
Change in mean Area	$(\Delta \bar{A}_t)$	$\bar{Y}_0 (\Delta \bar{A}_t)$
Change in mean yield	$(\Delta \bar{Y}_t)$	$\bar{A}_0 (\Delta \bar{Y}_t)$
Interaction between changes in mean yield and mean area	$(\Delta \bar{A}_t \Delta \bar{Y}_t)$	$(\Delta \bar{A}_t \Delta \bar{Y}_t)$
Change in area–yield covariance	$[(\Delta Cov(A_t Y_t))]$	$[(\Delta Cov(A_t Y_t))]$

Source: Hazell, 1982.

RESULTS AND DISCUSSION

Compound Annual Growth Rate Analysis: Pre- and Post-NFSM

Table 3 presents compound annual growth rates (CAGR) for area, production, and yield across major cereals during the pre- and post-NFSM periods. CAGR provides a consistent measure of long-term

growth patterns, allowing assessment of structural changes in crop performance before and after the policy intervention. For clarity, results are grouped by staple cereals, pulses, and coarse cereals to reflect NFSM's differentiated crop strategies.

The results indicate that a structural shift from area-led to yield-led growth, particularly in wheat, rice, and pulses. Wheat and rice recorded statistically significant improvements in production and yield growth in the post-NFSM period. Wheat yield rose from 0.8% to 1.6%, while rice yield increased from 1.0% to 1.9%, along with a slight increase in cultivated area. These outcomes are consistent with NFSM's core strategy of input-driven intensification. Pulses showed a substantial improvement, with area growth rising from -0.2% to 1.9%, production from -0.2% to 2.3%, and yield from 0.4% to 4.3%, all statistically significant. These changes align with targeted pulse interventions under NFSM, addressing domestic demand and nutritional needs.

Collectively, these improvements in rice, wheat, and pulses underscore NFSM's positive contribution to national food security. These crops form the backbone of the Public Distribution System (PDS) and national nutrition strategy, supplying

Table 2: Component of change in variance of production

Source of change	Symbol	Component of Change
Change in mean yields	$\Delta \bar{Y}_t$	$2\bar{A}_0 \Delta \bar{Y}_t Cov((A_0, Y_0)) + [2\bar{Y}_0 \Delta \bar{Y}_t + \Delta \bar{Y}_t^2] \Delta V(A_0)$
Change in mean areas	$\Delta \bar{A}_t$	$2\bar{A}_0 \Delta A_t Cov((A_0, Y_0)) + [2\bar{A}_0 \Delta \bar{A}_t \Delta A_t^2] \Delta V(Y_0)$
Change in yield variance	$\Delta V(Y_t)$	$\bar{A}_0^2 \Delta V(Y_t)$
Change in area variance	$\Delta V(\bar{A}_t)$	$\bar{Y}_0^2 \Delta V(\bar{A}_t)$
Interaction between changes in mean yield and mean area	$\Delta \bar{Y}_t \Delta \bar{A}_t$	$2\Delta \bar{Y}_t \Delta \bar{A}_t Cov((A_0, Y_0))$
Change in area–yield covariance	$\Delta Cov(A_t Y_t)$	$[2\bar{A}_0 \bar{Y}_0 - 2Cov((A_0, Y_0))] \Delta Cov(A_t Y_t) - \Delta Cov(A_t Y_t) - [Cov(A_t Y_t)]^2$
Interaction between changes in mean area and yield variance	$\Delta \bar{A}_t \Delta V(Y_t)$	$[2\bar{A}_0 \Delta \bar{A}_t + \Delta A_t^2] \Delta V(Y_t)$
Interaction between changes in mean yield and area variance	$\Delta \bar{Y}_t \Delta V(\bar{A}_t)$	$[2\bar{Y}_0 \Delta \bar{Y}_t + \Delta Y_t^2] \Delta V(\bar{A}_t)$
Interaction between changes in mean area and yield and change in area–yield covariance	$\Delta \bar{A}_t \Delta \bar{Y}_t$ $\Delta Cov((A_0, Y_0))$	$2\bar{Y}_0 \Delta A_t + 2\bar{A}_0 \Delta \bar{Y}_t + 2\Delta \bar{A}_t \Delta \bar{Y}_t \Delta Cov(A_t Y_t)$
Change in residual	ΔR	$\Delta V(A_t Y_t) - \text{Sum of other components}$

Source: Hazell, 1982.

Table 3: Compound Annual Growth Rate of Area, Production, and Yield for: Pre-NFSM vs. Post-NFSM Periods and Overall Period

Crop	Pre-NFSM			Post-NFSM			Overall Period		
	Area (ha)	Production (t)	Yield (t/ha)	Area (ha)	Production (t)	Yield (t/ha)	Area (ha)	Production (t)	Yield (t/ha)
Wheat	0.5**	1.3*	0.8*	0.7*	2.3*	1.6*	0.8*	2.1*	1.3*
Rice	0	1**	1*	0.4**	2.3*	1.9*	0.1*	1.7*	1.6*
Pulse	-0.2	0.1	0.3	1.9*	2.3*	4.3*	1.3*	2.4*	1.1*
Maize	2.3*	4.4**	2	1.3**	5.3*	3.9*	1.2*	2.6*	3.8*
Barley	1	5.1**	-4.1*	-4.1**	-0.7	3.6*	-1.3**	1	2.3*
Millet	-2.8*	-0.4	2.5	-0.5	1.8	2.3**	-2.1*	0.3	2.5*
Sorghum	-5.1	-5*	0.1	-6.5*	-1.7	5.2**	-4.8*	-4.3*	0.5

Source: FAOSTAT & author calculation.

Note: *, **, *** denotes the significant at 0.01%, 0.05 and 0.10%.

Table 4: Instability Index of Area, Production, and Yield for Pre-NFSM vs. Post-NFSM and Overall Period

Crop	Instability index (%)								
	Pre-NFSM			Post-NFSM			Overall Period		
	Area (ha)	Production (t)	Yield (t/ha)	Area (ha)	Production (t)	Yield (t/ha)	Area (ha)	Production (t)	Yield (t/ha)
Wheat	3.17	6.69	3.94	2.72	3.94	4.7	3.08	5.89	4.92
Rice	2.76	6.51	0.05	2.44	3.39	0.02	2.67	5.97	4.25
Pulse	6.22	9.99	0.06	5.14	10.11	0.07	7.67	14.86	0.08
Maize	1.94	6.92	0.06	3.5	4.71	0.04	3.19	8.21	0.06
Barley	5.8	9.26	0.05	8.46	9.56	0.04	8.93	11.42	0.06
Millet	5.3	13.34	0.12	3.61	8.02	0.05	5.56	10.63	0.08
Sorghum	4.53	6.87	0.08	7.28	13.09	0.09	6.02	10.53	0.11

Source: FAOSTAT & author calculation.

essential calories and proteins to vulnerable populations. Yield improvements in these staples directly strengthen food availability and stabilize procurement systems. This is consistent with recent findings by Ritchie *et al.* (2018) and Ashok *et al.* (2021), who demonstrate that improvements in domestic crop yields particularly in cereals and pulses are critical for ensuring long-term food security in India, especially in the context of rising demand and resource constraints.

Among coarse cereals, maize shows a comparatively stronger growth response. It sustained robust production and yield growth, although the growth in cultivated area declined, possibly due to land-use competition or agroecological constraints. In contrast, barley, millet, and sorghum demonstrated weak or negative area and production growth, despite yield improvements. These trends suggest that policy and market preferences still pose challenges to the growth of coarse cereals, as also noted by DeFries *et al.* (2023) and Davis *et al.* (2019).

This slowdown highlights the need for focused policy support and region-specific measures to promote coarse cereals and address the ongoing disparity in how resources are distributed.

Considering all crop groups, the CAGR findings highlight NFSM's contribution to enhancing productivity in staples and pulses, while also pointing to the need for differentiated policy attention to support coarse cereals in ecologically and economically constrained regions.

Instability Analysis of Cereal Production: Pre- and Post-NFSM

The variability in production, yield, and harvested area of major cereal crops during the pre- and post-NFSM periods was assessed using the Cuddy vella instability index, as presented in Table 4. This index captures the extent of fluctuations relative to the trend, allowing a consistent comparison across time periods and crops.

The findings indicate that the implementation of the National Food Security Mission coincided with reduced variability in rice and wheat production and area. Specifically, rice production instability declined from 6.51% to 3.39%, and wheat from 6.69% to 3.94%, while area instability also fell marginally in both cases. These reductions suggest that NFSM interventions contributed to more reliable production of key staples, thereby supporting the mission's goal of enhancing food grain stability and availability. In the case of pulses, area instability declined from 6.22% to 5.14%, indicating more consistent land allocation. However, production instability rose slightly from 9.99% to 10.11%, likely due to rainfall variability, pest incidence, as also noted by Sanjay *et al.* (2018). Yield instability remained low and stable. Given the nutritional importance of pulses in Indian diets, this finding suggests the need for improved resilience strategies in pulse cultivation.

Coarse cereals demonstrated uneven progress. Maize showed improved production stability (declining from 6.92% to 4.71%), although area instability rose slightly, suggesting shifting cultivation decisions. Barley showed higher fluctuations in both cultivated area and production, reflecting continued weak policy support. In contrast, millet showed reduced instability across both production and yield components, implying more favorable performance post-NFSM. Sorghum, however, registered increased instability across all three dimensions area, production, and yield highlighting persistent systemic challenges in its cultivation.

Overall, the decline in variability for rice, wheat, and

millet reflects progress toward NFSM's objective of stabilizing food grain output. However, the sustained or rising instability in pulses, barley, and sorghum emphasizes the need for more crop-specific interventions. These patterns are consistent with findings from Severini *et al.* (2016) and Miyasato (2022), who emphasized the importance of technology adoption and targeted management practices in mitigating production volatility.

Component of Change in Crop Average Production

The decomposition results of average cereal production growth using Hazell's (1982) framework are presented in Table 5. The method disaggregates production changes into mean area, mean yield, interaction effects, and area–yield covariance, providing insight into the underlying structural shifts during the post-NFSM period.

Yield emerged as the dominant driver for most cereals—accounting for over 50% of production growth in wheat (51.25%), rice (55.65%), and maize (67.25%)—reflecting the NFSM's emphasis on productivity enhancement through improved seed, input use, and agronomic practices. Pulses showed a balanced contribution from both yield (46.51%) and area (45.48%), indicating effective expansion as well as productivity gains. In contrast, barley and millet exhibited negative area effects (–169.4% and –1863%, respectively) with production growth driven almost entirely by yield. This suggests declining land allocation alongside technological gains, possibly due to policy neglect or reduced market incentives. Sorghum production was

Table 5: Components of change in average production

Sl. No.	Source of change	Symbol	Component of change (in percentage)						
			Wheat	Rice	Pulse	Maize	Barley	Millet	Sorghum
1	Change in mean area	$(\Delta \bar{A}_t)$	40.3	35.13	45.48	27.08	-169.4	-1863	100.08
2	Change in mean yield	$(\Delta \bar{Y}_t)$	51.25	55.65	46.51	67.25	298.94	2344.5	0.9
3	Interaction between changes in mean yield and mean area	$(\Delta \bar{A}_t \Delta \bar{Y}_t)$	8.67	9.41	7.87	5.76	-26.54	-392.2	-0.27
4	Change in area–yield covariance	$[(\Delta Cov(A_t Y_t))]$	-0.22	-0.19	0.14	-0.09	-2.93	10.74	-0.7
Total change in mean production			100	100	100	100	100	100	100

Source: FAOSTAT & author calculation.

primarily area-driven (100.08%), with minimal yield response, highlighting limited technological uptake. Millet was the only crop showing a strong positive area–yield covariance (10.74%), indicating aligned growth in area and productivity—an uncommon but favorable outcome in cereal systems, where inverse relationships often dominate due to agro-climatic variability or constrained input access.

When compared to past decomposition studies, these findings partially align with Hazell (1984), who reported more balanced contributions of area and yield in earlier decades. However, the current results reflect a clear shift in the underlying production system—from land-led expansion to technology-driven intensification—consistent with the NFSM’s input-oriented approach. Unlike Hazell’s period, where area variability played a significant role, present trends show reduced or negative area contributions in several cereals, particularly coarse grains, suggesting evolving land-use dynamics and changes in policy prioritization. Collectively, these consistencies indicate that Indian cereal systems have progressively moved toward yield-dependent strategies with diminishing reliance on area expansion. These results underscore the need for differentiated policy strategies that emphasize area stabilization for land-constrained

crops and sustained technological investment in low-yield-responsive cereals.

Production Variance and its Component of Change

Table 6 presents the decomposition of production variance for major cereals during the NFSM period, offering insights into the structural factors driving output instability. Following a variance decomposition framework, the change in total production variability is attributed to shifts in mean yield and area, yield and area variance, area–yield covariance, and residual effects.

Yield variance emerged as the primary contributor to production instability in most cereals. In wheat (110.79%), pulses (74.4%), maize (228.93%), and sorghum (85.44%), changes in yield variability explained the majority of production fluctuations. This dominance suggests that while NFSM-led productivity improvements have raised yields, the consistency of these gains remains uneven. In rice, yield variance contributed moderately (29.98%) but was overshadowed by a large positive area–yield covariance (40.84%), indicating that simultaneous increases in area and yield tended to magnify production variability. A similar pattern was observed in maize and sorghum, where

Table 6: Components of change in variance of production

Sl. No.	Source of changes	Symbol	Component of change (in percentage)						
			Wheat	Rice	Pulse	Maize	Barley	Millet	Sorghum
1	Change in mean yields	$\Delta \bar{Y}_t$	28.61	-6.75	8.01	-58.73	5639.93	8.52	0.16
2	Change in mean areas	$\Delta \bar{A}_t$	40.65	11	27.3	40.91	485.54	-29.25	-43.67
3	Change in yield variance	$\Delta V(Y_t)$	110.79	29.98	74.4	228.93	-2861	95.42	85.44
4	Change in area variance	$\Delta V(\bar{A}_t)$	59.22	9.12	1.73	-103.5	10818.9	18.48	16.09
5	Interaction between changes in mean yield and mean area	$\Delta \bar{Y}_t \Delta \bar{A}_t$	0.07	-2.08	1.25	-0.86	-176.2	0.01	-0.07
6	Change in area–yield covariance	$\Delta Cov(A_t Y_t)$	-125.06	40.84	30.94	64.75	-10147	-20.89	135.42
7	Interaction between changes in mean area and yield variance	$\Delta \bar{A}_t \Delta V(Y_t)$	40.65	11	27.3	40.91	485.54	-29.25	-43.67
8	Interaction between changes in mean yield and area variance	$\Delta \bar{Y}_t \Delta V(\bar{A}_t)$	28.21	5.54	0.65	-48.73	3654.7	8.6	-0.09
9	Interaction between changes in mean area and yield and change in area–yield covariance	$\Delta \bar{A}_t \Delta \bar{Y}_t$	-52.97	19.84	11.82	21.01	-808.65	-0.18	-44.33
10	Change in residual	$\Delta Cov(A_0, Y_0)$	-30.15	-18.5	-83.38	-84.7	-6991.3	48.56	-5.29
Total change in variance of production			ΔR	100	100	100	100	100	100

Source: FAOSTAT & author calculation.

strong positive covariance (64.75% and 135.42%, respectively) implies that synchronized growth in area and productivity, though beneficial for output, may heighten instability if not balanced. Positive area–yield covariance values, while reflecting coordinated expansion, are often associated with increased volatility—especially when both dimensions are sensitive to external factors such as climate variability or market-linked incentives.

Barley and millet exhibited contrasting dynamics. In barley, production variance was largely attributable to extreme fluctuations in both area (10,818.9%) and mean yield (5,639.9%), suggesting erratic cultivation behavior and poor synchronization between land use and productivity. Millet's production variability was also primarily yield-driven (95.42%), though it was partially stabilized by reductions in area (–29.25%) and a negative area–yield relationship (–20.89%). This indicates that contraction in land allocation may have had a stabilizing influence. Sorghum's instability, though also yield-led, was further amplified by a highly positive area–yield covariance, reinforcing its sensitivity to concurrent changes in area and productivity.

These findings are consistent with Larson et al. (2004), who found that yield variance had become the dominant contributor to cereal production instability in India during the post-Green Revolution period, while area variance declined and area–yield covariance was typically weak or destabilizing. The fact that this trend continued during the NFSM period shows that cereal production still depends heavily on productivity gains, which remain unstable due to changes in climate and input use.

From a policy perspective, the results suggest that although NFSM's focus on increasing yields has helped boost cereal production, maintaining these gains over time is equally important especially for crops where unstable yields pose a major risk. For crops like barley and sorghum, where both yield and area show high instability, a more comprehensive approach is needed one that combines better land-use planning with productivity improvements. Additionally, the strong positive link between area and yield seen in crops like rice, maize, and sorghum points to the need for carefully planned expansion strategies. These strategies should aim to balance increases in both area and yield to avoid large swings in total production. Overall,

these findings highlight the importance of making production stability a key goal of agricultural policy, particularly in regions and crops where high fluctuations in output can limit the long-term benefits of productivity growth.

CONCLUSION

This study analyzed the factors driving changes in cereal crop production, with particular focus on the average and variance of production for rice, wheat, pulses, and coarse cereals. A key objective was to assess whether the National Food Security Mission (NFSM) influenced the growth and stability of cereal production in India.

The findings indicate that NFSM has a significant impact, contributing to increased growth in both yield and area for most crops. The mission has been especially effective in enhancing the productivity of pulses, which traditionally lagged in technological adoption. The decline in instability indices across key crops reflects NFSM's role in promoting system-wide resilience and stability in Indian agriculture.

The Hazell decomposition analysis shows that growth in average production was primarily driven by changes in mean yield and mean area. However, for coarse cereals, substantial variation in area effects signals structural challenges in land allocation. This highlights the need for targeted policy interventions to stabilize crop areas and sustain long-term growth.

The success of NFSM offers several insights for future agricultural policy. First, continued emphasis on high-yielding varieties and improved agronomic practices is essential. Second, the observed improvements in production stability suggest the importance of policies that enhance resilience to climatic and market risks. Third, integrating digital tools and precision agriculture can further improve productivity and reduce risk exposure. Enabling the adoption of such technologies will require investment in rural infrastructure, extension services, and capacity-building for farmers.

In summary, NFSM has played a pivotal role in improving the productivity, growth, and stability of key cereal crops in India. The improvements in yield and production, alongside reduced instability, underline its contribution to national food security. To sustain and build on this progress, future

efforts must focus on innovation, inclusivity, and resilience—ensuring that all farmers benefit from advancements in agricultural systems. Moreover, the limited gains observed in coarse cereals highlight the need to adapt NFSM interventions to regional agro-ecological conditions. Strengthening decentralized procurement, promoting climate-resilient varieties, and enhancing market linkages are essential to better integrate coarse cereals into India's broader food security strategy.

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