International Journal for Multidisciplinary Research (IJFMR)

E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Trends in Yield, Area, and Production of Food grains in India: an ARDL Approach

Mr. Shaharshad C T[1], Dr. K Manikandan[2], Ms. M Priyadharshini[3], Mr. Muhammad Rishad K P[4]

[1, 3, 4]Research Scholar, [2]Associate Professor

[1, 2, 3, 4]Department of Economics, The Gandhigram Rural Institute Deemed to be University, Dindigul – Tamil Nadu, 624302

Abstract

An attempt is made in this paper to examine the patterns in the area, production, and productivity, of India's major food grain crops. Statistical methods such as trend analysis asaverage annual growth rate, and Auto-Regressive Distributed Lag model are used. The ARDL Model is used to determine the short-run and long-run relationship between the independent variables area, production on the dependent variable yield of foodgrainfrom 1965 to 2022. The study found that in the short-run there is a significant positive impact of area and second lag of yield on the dependent variable yield of food grains in India and the production is not significantly influencing the yield of foodgrains. On the other hand, in the long-run cointegrating relationship among the variables based on the bound test results shows that the production is having a significant positive impact on the yield of foodgrains and the area under cultivation is showing an insignificant impact on the yield of foodgrains. The corresponding Error Correction Mechanism indicates the high speed of adjustment towards the equilibrium relationship among the variables.

INTRODUCTION

The population of the world is growing at an alarming rate, especially in developing nations. The planners of these nations and international organisations continue to face the difficult problem of feeding this growing population (Mishra et al., 2015). Over the years, the Indian agriculture sector has experienced a significant transition from a serious food crisis to food grain production self-sufficiency. With a five-fold rise in food grain production from 50 million tonnes in 1950–51 to roughly 287.17 million tonnes in 2018–19, India has shifted away from reliance on food aid and is now a net food exporter (Indiastat, 2018). In addition to accounting for 13–14% of the country's GDP, agriculture employs about 60% of the workforce directly or indirectly, suggesting that many people rely on it for their livelihoods. It supplies raw materials to numerous businesses and aids in capital formation. In fact, agriculture serves as the foundation for the agro-based industry. With its backward and forward links, it offers industrial products a market and tremendous advantages to the whole economy. By serving as the foundation for agro-related services, it aids in the growth of the tertiary sector. More importantly, it provides food for the world's first-largest population, regardless of whether it works in the agricultural or non-agricultural sectors. Food and other agricultural products can also be obtained through international trade, but an excessive reliance on imports of goods related to food can have a negative impact on a country's independence in the global political sphere, especially during pivotal moments. Such situations have previously occurred in India.Furthermore, relying on foreign trade for agricultural products seems like an impracticalstrategy for a country with vast land and human resources like India.

The issue of food security that the majority of developing nations face, food grain production is significant.The necessity of increasing foodgrain production and ensuring food security in India has grown due to the country's size, population growth rate, and proportion of the population living in poverty (Krishnan Kutty, 2022). Food grain production is important since most developing countries struggle with food security.Given India's size, rate of population growth, and percentage of the people living in poverty, there is an increasing need to increase foodgrain production and provide food security in the country. Cereals and pulses are the two primary components of an Indian meal. Rice and wheat are staple foods for almost everyone.Food grain production is important for most developing countries who struggle with food security including India.As a result, suitable measures ought to be implemented to promote agricultural growth. Prior to implementing any development initiatives, it is necessary to determine the current production, productivity, and area patterns that are impeding development.

India's agricultural productivity patterns were examined by Kumar and Mittal (2006). The results showed that the two main staple food crops, wheat and paddy, had done well in terms of productivity increases. According to a study by Larson et al. (2004), the majority of crops have seen increases in production as a result of rising agricultural yields and area.According to Priscilla et al. (2017), the increased usage of high-yielding verities and fertilisers over 1995–1996 to 2004–2005 resulted in a larger yield contribution to foodgrain production, even combating the area impact and interaction effect. Dhanalakshmi (2017) discovered that, with a negative compound annual growth rate (CAGR) of 0.19 percent, the total foodgrain cultivated area decreased from 95.32 million hectares in 2000-01 to 92.43 million hectares in 2015-16.

The quantity of agricultural production in relation to an input or group of inputs is known as agricultural productivity. The measures can include total factor productivity (TFP) metrics, which examine the amount of output in relation to a set of inputs, or partial productivity metrics, such as output per unit of labour or land. Against this significance, the paper is predicated on a partial productivity measure that calculates foodgrain output in kilogrammes per hectare of land. The Data for 2022-23 are based on Third Advance Estimates in Ministry of Agriculture & Farmers Welfare, Government of India is the source of the foodgrain productivity data. In this regard,an attempt was made to capture the trends of area, production and productivity of each crop. In order to provide a more quantitative dimension to the study we have made use of Auto Regressive Distributed Lag (ARDL) Model. In this we have used aggregated data of all foodgrains together for 55 years annually from 1965 to 2022.

REVIEW OF LITERATURE

There is an enormous amount of research studies are available at both the national and international levels that aims to analyse the factors that contributed to the development in agricultural output over time.Minhas and Vaidyanathan (1965) decompose agricultural expansion into twocomponents, namely area and yield, as part of a study that attempted to explain how various factors contributed to the increase in agricultural production. This study attempts to calculate the proportion of the production increase that can be attributed to the expansion of the area and yield or productivity. They have further pared up TFP into elements like extension, research, infrastructure, education, and the health of natural resources. They contend that a variety of factors, including input-output prices, technological advancements, institutions, infrastructure, policy initiatives, and more, influence input growth itself. Evenson and Jha (1973), Kumar and Rosegrant (1994), Rozelle et al. (2003), and Coelli and Rao (2003) are a few research that make use of the TFP concept.

There is literature that tries to measure and analyse agricultural productivity in addition to this that decompose the agricultural growth into its component parts. The first research in this area was done by Schultz in 1953 and Solow in 1957. Three methods of measurement such as the parametric method, the accounting method, and the non-parametric methodhave been used in the majority of these tests. Because it requires creating productivity indices rather than estimating, the accounting method is the most practical of these three approaches to use. There are several studies that quantify productivity, such as those that assess productivity for the whole agricultural sector, for specific crops nationwide, or for states or areas within the nation. There are several studies conducted on the basis of productivity.

For the crop sector in the Indo-Gangetic Plains, Kumar et al. (2004) calculated the proportion of total factor productivity and the yearly growth in total factor productivity for the years 1981–1990, 1990–1996, and 1981–1996. In order to perform research at a disaggregated level, they also calculated the annual rise in TFP and the fraction of TFP for the Lower, Upper, Mid, and Trans Gangetic Plains. Although there is a wealth of literature on agricultural productivity or the productivity of particular crops, it is not particularly pertinent to discuss it here because the goal of the current study is not to break down the growth in agricultural output into its component parts or to calculate the productivity of any one factor or the productivity of all factors.

METHODOLOGY OF THE STUDY

The study primarily focuses on the analysis of trends and patterns of various foodgrain crops in India since 1965 to 2022. More importantly this study makes an in depth analysis of the short-run and long-run relationship among the independent variables area and production of foodgrains on the dependent variable yield of food grains in India by using the Auto-Regressive Distributed Lag (ARDL) Model based on the unit root test which shows the combination of I(0) and I(1) series of the selected time series data. The ARDL model used for the study is stated below:

$$Yield_t = \propto_0 + \beta_1 Yield_{t-1} + \beta_2 Yield_{t-2} + \beta_3 Area_t + \beta_4 Area_{t-1} + \beta_5 Production + \epsilon_t$$

The data on the variables area, production and yield of the foodgrains are obtained from the Third Advance Estimates for 2022-23, Ministry of Agriculture & Farmers Welfare, Government of India.

Whereas$\propto_0$ is the intercept term and β_1, β_2, β_3, β_4 and β_5 are corresponding coefficients.

1. **RESULTS AND DISCUSSION**

3.1 EXTENT OF AREA, PRODUCTION AND YIELD OF RICE CULTIVATION

Table one provides data on the area in lakh hectares, production volume, and yield of rice cultivation in the six decades from 1965 to 2022. By measuring each decade, we take the area growth rate, production and yield of rice cultivation. In this table, the cultivable area increased from 373.8 lack hectares during 1965-1975 to 446.2 lack hectares in the recent decade of 2016-2022. Whereas the production increased than area by 402.9 lack tons to 1185.5 lakh tons between 2016 and 2022. The yield increased substantially, reaching 2672.2 kg per hectare in the recent decade, only from 1078.6 kg per hectare.

Growth trends varied across periods. The highest area growth (2.1Per cent) occurred in the most recent period (2016-2022), whereas production saw its highest growth rate (4.45Per cent) in the earliest decade (1965-1975). Yield growth, indicating efficiency gains per unit of land, showed consistent improvement across periods, peaking between 1976-1985 with a 3.94Per cent growth rate. These data results the combined impact of technological advancements such as high yielding variety of crops, fertilizers, pesticides and irrigation facilities which evolving agricultural practicesof green revolutioninfluences on crop production over the years.

TABLE 1 EXTENT OF AREA, PRODUCTION AND YIELD OF RICE CULTIVATIONIN INDIA

Period	Avg. Area (in lakh ha)	Avg. Prod. (in lakh tons)	Avg. Yield (kg/ha)	Area Growth Rate (Per cent)	Prod. Growth Rate (Per cent)	Yield Growth (Per cent)
1965-1975	373.8	402.9	1078.6	1.05	4.45	0.85
1976-1985	400.1	529.5	1337.7	-0.38	2.86	3.94
1986-1995	421.5	707.7	1675.2	0.74	1.25	2.92
1996-2005	435.1	858.9	1966.1	0.57	2.22	1.57
2006-2015	435.6	993.6	2223.6	-0.36	1.55	1.70
2016-2022	446.2	1185.5	2672.2	2.1	2.55	1.89

Note: Data for 2022-23 are based on Third Advance Estimates.

Source: Ministry of Agriculture & Farmers Welfare, Government of India.

During the period of 1965-1975, area growth was (1.05 percent) and production growth was (4.45 percent) of rice cultivation were positive, but yield growth was modest at 0.85 percent. In this period, there was significant expansion in the rice cultivated area, and production growth was driven mainly by this expansion rather than yield improvements.In the phase of 1976-1985, yield growth was substantial at 3.94 percent, while area growth declined (-0.38 percent) and production growth slowed down (2.86 percent).This period marks a shift from expansion to productivity improvements. Inthe next decade of 1986-1995, area growth rebounded to 0.74 percent, while production growth slowed to 1.25Per cent, and yield growth was 2.92Per cent.This decade maintained the focus on improving yield while adding some new cultivated areas.The decade of 1996-2005, area growth remained positive at 0.57Per cent, with production and yield growth at 2.22Per cent and 1.57Per cent, respectively.This period balanced expansion with productivity improvements.Negative area growth, modest production growth (1.55Per cent), and continued yield improvement (1.70Per cent) were showed in the decade of 2006-2015. This decade saw minimal area expansion, with most gains coming from increased productivity. In the last decade of 2016-2022 depicts the strong area growth (2.1Per cent), production growth (2.55Per cent), and yield growth (1.89Per cent) under rice cultivation.

1.2 EXTENT OF AREA, PRODUCTION AND YIELD OF WHEAT GROWTH RATE

This table 2 provides a data on cultivated area, production volumes, and yield of wheat per hectareacross six decades, from 1965 to 2022, capturing cultivated area, production volumes, and yield per hectare. Byexamining data for each decade, we would be able to observegrowth in both production and yield, highlighting advancements in agricultural efficiency and output.

Initially, between 1965 and 1975, area and production increased in particular, with production growing at a remarkable rate of 13.0Per cent, supported by a strong yield growth of 3.3 ofPer cent. In the following decade, 1976-1985, both area and production growth rates slowed down but still remained robust, with production expanding at 5.9Per cent and yield improving by 4.2Per cent.

From 1986 to 1995, yield growth continued steadily at 3.6Per cent, contributing to a 3.7Per cent increase in production, even as area growth stabilized. The trend of yield-driven production growth persisted through the 1996-2005 and 2006-2015 periods, with yield improvements gradually slowing, reflecting diminishing marginal gains in output per hectare. However,yield in 2006-2015 reached 3,081.4 kg/ha, depicting significant productivity advancements.

In the most recent period, 2016-2022, yield growth tapered to 1.3Percent, though production still expanded by 2.4Per cent, reaching an average of 1,029.2 lakh tons. Despite minimal area growth, yield improvements have been the primary driver of production increases over time, illustrating the impact of technology and efficiency on agricultural productivity. This data shows the sustained progress in agricultural yields and the shift from extensive to intensive production methods over recent decades.

TABLE 2 EXTENT OF AREA, PRODUCTION AND YIELD OF WHEAT GROWTH RATE

Decade	**Avg. Area (lakh ha)**	**Area Growth (Per cent)**	**Avg. Production (lakh tons)**	**Production Growth (Per cent)**	**Avg. Yield (kg/ha)**	**Yield Growth (Per cent)**
1965-75	178.7	4.25	215.2	13.0	1246.3	3.3
1976-85	228.6	0.84	373.8	5.9	1698.7	4.2
1986-95	240.4	0.77	506.4	3.7	2286.5	3.6
1996-05	264.8	0.95	682.1	3.1	2684.0	2.1
2006-15	299.8	0.17	883.4	2.9	3081.4	1.7
2016-22	306.9	0.38	1029.2	2.4	3467.6	1.3

Note: Data for 2022-23 are based on Third Advance Estimates.

Source : Ministry of Agriculture & Farmers Welfare, Government of India.

The area under wheat cultivation increased steadily from 178.7 lakh hectares in the 1965-75 period to 306.9 lakh hectares in 2016-22. The area growth rate was highest in the initial period (1965-75) at 4.25 per cent and then dropped significantly in subsequent decades.From the 1976-85 period onwards, area growth rates had been generally low, fluctuating between 0.17 per cent and 0.95 per cent.In the most recent period (2016-22), the area growth rate remained modest at 0.38 per cent, indicating a slowdown rate in the expansion of wheat cultivation area.The initial rapid growth in area (1965-75) reflects a period of agricultural expansion, due to the Green Revolution and the introduction of high-yielding wheat varieties.However, from the late 1970s onward, the growth in the cultivated area slowed, suggesting that wheat acreage may have approached a land availability or policy-driven ceiling, with limited further expansion possible in the recent decades. Average production of wheat rose significantly across each decade, starting from 215.2 lakh tons in 1965-75 and reaching 1029.2 lakh tons by 2016-22.Production growth was highest in the early decades, with a notable peak at 13.0 per cent in 1965-75.From 1976-85 onwards, the growth rate declined but remained positive, stabilizing between 2.4 per cent and 5.9 per cent.In the recent decade (2016-22),production growth continued at 2.4 per cent, though at a slower rate compared to earlier decades.The high initial growth in production is likely due to increased acreage and the introduction of improved agricultural practices and wheat varieties during the Green Revolution. Although growth rates have slowed since then, production has continued to increase due to improved yields, even as area expansion has levelled off.Wheat yield per hectare has steadily increased over the decades, from 1246.3 kg/ha in 1965-75 to 3467.6 kg/ha in 2016-22.The yield growth rate started at 3.3 per cent in 1965-75 and was highest during 1976-85 at 4.2 per cent, driven by new farming practices and technologies.From 1986-95 onwards, yield growth rates gradually declined, reaching 1.3 per cent in the latest decade (2016-22),accounting for diminishing marginal returns.

The steady increase in yield reflects advancements in agricultural technology, such as HYV seed varieties, fertilizers, and irrigation practices. However, the declining growth rate suggests that yield improvements may be reaching a plateau, likely due to diminishing marginal returns obtained in agriculture.

1.3 EXTENT OF AREA, PRODUCTION AND YIELD OF COARSE CEREALS IN INDIA

This section (table 3) presents a comprehensive view of agricultural trends from 1965 to 2022, focusing on cultivated area, production volume, and yield per hectare, and their respective growth rates. Over these six decades, it becomes clear that while cultivated area has consistently decreased, production and yield have continued to increase, indicating a more intensive and efficient agricultural practices.

In the early period from 1965 to 1975, agricultural production expanded significantly, with a 6.5 per cent average annual growth rate, despite a slight decrease in cultivated area. This growth was driven by a remarkable 7.2 per cent increase in yield, which rose to an average of 613.9 kg/ha. The following decade, 1976-1985, saw a continuation of these trends, as production grew by 3.7 per cent and yield by 6.9 per cent, even as the area contracted further to 0.8 per cent.

The most dramatic reduction in cultivated area occurred from 1986 to 1995, with a 2.0 per cent, while yield growth reached a peak of 7.7 per cent, supporting a 3.3 per cent rise in production. This period marked the start of a shift toward maximizing productivity from smaller areas. Between 1996 and 2005, area decline continued at a rate of 1.6 per cent, while production grew at a slower rate of 2.7 per cent, supported by a still-robust yield growth of 5.4 per cent.

From 2006 to 2015, yield improvements of 5.7 per cent enabled production growth to accelerate to 5.4 per cent, even as cultivated area decreased by 2.3 per cent. In the latest period, 2016-2022, this pattern persisted: while cultivated area fell to 3.6 per cent, average production rose at 5.0 per cent, with yields reaching 1,792 kg/ha.

These trends reflect an ongoing shift towards more efficient use of land, leveraging technological advancements, improved agricultural practices, and innovations that have allowed for increased productivity despite a reduction in cultivated area.

TABLE 3 EXTEND OF AREA, PRODUCTION AND YIELD OF COARSE CEREALS IN INDIA

Decade	Average Area (Lakh Ha)	Average Area Growth Rate (per cent)	Average Production (LakhTonnes)	Average Production Growth Rate (per cent)	Average Yield (Kg/Ha)	Average Yield Growth Rate (per cent)
1965-75	453.8	-0.25	278.3	6.5	613.9	7.2
1976-85	416.8	-0.8	290.5	3.7	694.4	6.9
1986-95	348.1	-2.0	317.8	3.3	913.2	7.7
1996-05	307.4	-1.6	328.7	2.7	1071.0	5.4
2006-15	274.4	-2.3	365.6	5.4	1370.7	5.7
2016-22	243.5	-3.6	429.7	5.0	1792.0	3.3

Note: Data for 2022-23 are based on Third Advance Estimates.

Source : Ministry of Agriculture & Farmers Welfare, Government of India.

The first decade showed the moderate growth in area under coarse cereals in the early years (up to 473 lakh hectares in 1966-67) but started declining by the end of the period, with an average annual decline of -0.25 percent.Production grew steadily from 214.2 lakh tonnes in 1965-66 to 305.5 lakh tonnes in 1970-71. The average production growth rate was 6.5 percent, showing healthy increase due to technological interventions and favourable weather conditions.The average yield grew at7.2 percent, reflecting technological advancements, such as better crop varieties and fertilizers, leading to higher productivity per hectare.During the decade of 1976-85, the area continued to decline, though at a slower rate than in the previous decade (-0.8% per year). The reduction in area could be attributed to shifts towards more profitable crops like rice and wheat. The production of coarse cereals increased moderately by 3.7 percent, reflecting that the productivity of land was improving, even though the area under coarse cereals was shrinking. Theyield growth remained strong at 6.9 percent, driven by increased mechanization, irrigation, and adoption of new technologies such as hybrid seeds.There was a significant decline in area at -2.0 percent, likely due to further shifts towards other crops and decreasing demand for coarse cereals during 1986-95 decade.The production growth remained positive at 3.3 percent, which is slightly slower than the previous decade, but still reflects the impact of continued improvements in agricultural practices.The yield growth rate increased to 7.7 percent, which is higher than the previous decades, driven by ongoing improvements in farming techniques and crop genetics.In the decade of 1996-05, The decline in area continued at a rate of -1.6 percent, indicating a continued shift in cropping patterns away from coarse cereals.The production grew at a more modest 2.7 percent, reflecting the impact of shrinking area despite higher productivity.The growth in yield was 5.4 percent, indicating that while there was still improvement in per hectare production, the rate of increase was slowing as yields approached their biological limits without major innovations.The decade of 2006-2015, the area decreased at -2.3 percent, further reinforcing the trend of declining area under coarse cereals due to urbanization, and preferences for other crops.Despite the decline in area, production increased by 5.4 percent, showing the power of technological improvements in boosting output per unit of land.Yield continued to increase at 5.7 percent, but the rate of growth was slower than in the previous decades, suggesting that improvements were more incremental and less revolutionary than before.In the period of 2016-22, the rate of area reduction accelerated to -3.6 percent annually, reflecting a continued shift away from coarse cereals toward other agricultural products, possibly driven by market demand, policy changes, or changing dietary patterns.The production grew at 5.0 percent despite the shrinking area, demonstrating that technological innovations and better management practices helped offset the decline in land area.The yield growth slowed to 3.3 percent, which is the lowest of all the decades, suggesting that achieving higher yields may have become more challenging in recent years, possibly due to soil degradation, water scarcity, or stagnating technological advancements.

There has been a steady decline in the area under coarse cereals over the decades, with the sharpest decline occurring in the last two periods (2006-22). This decline could be attributed to changing dietary patterns, the increasing shift towards more water-intensive crops like rice and wheat, and urbanization.Despite the declining area, production has consistently grown, albeit at a slower pace in the later decades. This suggests that yield improvements have been able to compensate for the shrinking area to some extent. The yield growth was strong in the earlier decades (1965-95), driven by technological improvements and innovations. However, in the last two decades, yield growth has slowed down, possibly indicating that the rate of productivity increase per hectare has plateaued. Factors such as soil health, climate change, and water scarcity may be contributing to this slowdown.

In the early decades (1965-95), innovations in agricultural practices, better irrigation techniques, and the introduction of high-yielding varieties were major drivers of growth in production and yield.As we move into the 21st century, the growth rates of area, production, and yield have started to slow down, reflecting challenges such as limited land availability, climate change, and decreasing returns from conventional agricultural practices.To sustain production growth in the face of shrinking area, the focus will need to shift toward sustainable intensification, with advancements in precision farming, better water management, and crop diversification. The slower rate of yield growth also suggests the need for breakthroughs in agricultural technology to increase productivity in the coming decades.

3.5 EXTENT OF AREA, PRODUCTION AND PRODUCTIVITY OF PULSES IN INDIA

The table five provides an overview of the trends in area, production, and productivity of pulses over nearly six decades, from 1965 to 2022. Examining the data across six periods, we see significant changes in the cultivation area and marked improvements in both production and yield, illustrating the evolution and intensification of pulse farming.

In the earliest period, 1965-1975, the average area under pulse cultivation was 224.4 lakh hectares, with a production of 1,085.2 lakh tonnes and an average yield of 506.4 kg/ha. During this time, there was limited growth in area, production, and yield. However, from 1976 to 1985, area increased by 2.3per cent, production rose by 5.5 per cent, and yield grew by 5.1 per cent, reflecting early advancements in pulse farming practices.

The following decade (1986-1995) saw the cultivated area stabilized, with a slight decline of 0.1per cent, while production and yield continued to improve, growing by 7.7 per cent and 7.0 per cent, respectively. In 1996-2005, area contracted slightly by 0.4 per cent, but production and yield still grew by 3.7 per cent and 3.6 per cent, indicating gains in productivity.

A significant shift occurred from 2006 to 2015, with area expanding by 1.6 per cent and production jumping by 18.3 per cent, accompanied by a 12.5 per cent increase in yield, reaching 664.0 kg/ha. In the most recent period, 2016-2022, area growth accelerated to 5.8 per cent, and production increased by 10.4 per cent, supported by an impressive 25.1 per cent growth in yield, bringing the average yield up to 830.4 kg/ha.

These data reflect the transformative impact of modern agricultural practices, research, and technology on pulse production. The substantial improvements in yield and production, especially in recent decades, suggest that pulse cultivation has become more efficient and productive, addressing rising demand and contributing to global food security.

TABLE 4 EXTENT OF AREA, PRODUCTION AND PRODUCTIVITY OF PULSES IN INDIA

Decade	Average Area (lakh Ha)	Average Area Growth Rate (per cent)	Average Production (lack Tonnes)	Average Production Growth Rate (per cent)	Average Yield (Kg/Ha)	Average Yield Growth Rate (per cent)
1965-1975	224.4	-	1085.2	-	506.4	-
1976-1985	229.6	2.3	1145.0	5.5	532.3	5.1
1986-1995	229.4	-0.1	1233.0	7.7	569.5	7.0

1996-2005	227.5	-0.4	1279.0	3.7	589.9	3.6
2006-2015	244.4	1.6	1512.9	18.3	664.0	12.5
2016-2022	292.0	5.8	1671.1	10.4	830.4	25.1

Note: Data for 2022-23 are based on Third Advance Estimates.

Source : Ministry of Agriculture & Farmers Welfare, Government of India.

The area devoted to pulses has been increasing across all decades, with the highest average area in the most recent decade (2016-2022) at 292.0 lakh hectares, up from 224.4 lakh hectares in 1965-1975. This suggests that pulses farming has grown significantly over the years.The largest growth in area occurred between 2016-2021 (a growth rate of 5.8 per cent), showing a consistent and rapid expansion in pulses cultivation over the past decade.The average area growth rate shows a slow and steady increase over time. The growth rate was highest in the 2016-2021 period (5.8 per cent), reflecting a sharp expansion in pulses area.Decades prior to that, the growth rate remained relatively stable, with the 1976-1985 period seeing an increase of 2.3 per cent, and later decades like 1986-1995 experiencing almost negligible growth (-0.1 per cent).Pulses production has shown a steady increase across all decades, with the largest jump in the 2006-2015 decade (from 1279 lakh tonnes in the 1996-2005 period to 1512.9 lakh tonnes) with a growth rate of 18.3 percent. The increase in production is a direct result of higher yields and expanded area under cultivation.Yield per hectare has steadily improved across the decades, from 506.4 kg/ha in the 1965-1975 period to 830.4 kg/ha in the 2016-2021 period, reflecting advances in agricultural practices, seed technology, and irrigation methods.Yield growth rates were relatively modest until the 2000-2010s when significant advances in farming practices and technology began to show results.The most remarkable improvement came between 2016-2021, with an increase of 25.1 per cent in yield per hectare.

Auto Regressive Distributed Lag Model

In the earlier sections, the analysed the data on area, production and productivity of rice, wheat, coarse cereal and pulses pertaining to the period observations from 1965-2022. The analysis was carried out for 6 decadal points of time. From the tabular analysis, an attempt was made to capture the trends of area, production and productivity of each crop. In order to provide a more quantitative dimension to the study we have made use of Auto Regressive Distributed Lag (ARDL) Model. In this we have used aggregated data of all foodgrains together for 55 years annually from 1965 to 2022.

The paper set the model of the following equation for each period in the short-run

$$\square\square\square\square\square_{\square} = \propto_0 + \square_1 \square\square\square\square\square_{\square-1} + \square_2 \square\square\square\square\square_{\square-2} + \square_3 \square\square\square\square_{\square} + \square_4 \square\square\square\square_{\square-1} + \square_5 \square\square\square\square\square\square\square\square\square\square + \epsilon_{\square}$$

Where,

$\square\square\square\square\square\square_{\square}$: Yield at time (the dependent variable).

Independent Variable

$\square\square\square\square\square_{\square-1}$= Yield at previous time period (t-1)

$\square\square\square\square\square_{\square-2}$= Yield at two periods before (t-2)

$\square\square\square\square_{\square}$= The area under consideration at time t

$\square\square\square\square_{\square-1}$= The area under consideration at the previous time period (t-1)

Production: production value, which is assumed to have not to have a time lag

The paper set the model of the following equation

Where,

$$\square_{\square} = \square_{0} + \sum_{\square=1}^{\square} \square\square\square_{\square-1} + \sum_{\square=0}^{\square} \square_{\square}\, \square_{\square-\square} + \sum_{\square=0}^{\square} \square_{\square}\square_{\square-\square} + \epsilon_{\square}$$

The long run relationship can be derived by eliminating the lagged value (assuming the system reaches equilibrium where $\Delta\square_{\square} = 0$, that is no changes over time). This results,

$$\square_{\square} = \frac{\square_{0} + \sum_{\square=0}^{\square} \square_{\square}\, \square_{\square} + \sum_{\square=0}^{\square} \square_{\square}\square_{\square}}{1 - \sum_{\square=1}^{\square} \square\square}$$

Here,

$\frac{\square_{\square}}{1-\sum_{\square=1}^{\square} \square_{\square}}$: coefficient indicating the long run effect of $\square_{\square}$ (Area) on $\square_{\square}$

$\frac{\square_{\square}}{1-\sum_{\square=1}^{\square} \square_{\square}}$: coefficient indicating the long run effect of $\square_{\square}$on $\square_{\square}$ yield

If the ARDL model have lag for each variable

$$\square\square\square\square\square_{\square} = \propto_{0} + \square_{1}\square\square\square\square\square_{\square-1} + \square_{2}\square\square\square\square\square_{\square-2} + \square_{3}\square\square\square\square_{\square} + \square_{4}\square\square\square\square_{\square-1} + \square_{5}\square\square\square\square\square\square\square\square\square\square + \epsilon_{\square}$$

The long run equation is

$$\frac{\square_{0} + \square_{0}\square + \square_{1}\square + \square_{1}\square}{1 - \square_{1}}$$

Where A and P are lagged values of area and production

The long-run coefficients are ratios of the sum of short-run coefficients to the adjustment factor $1 - \square_{1}$which reflects the speed of adjustment to the long-run equilibrium.The coefficients represent the total impact of area and production on yield when the system is in equilibrium.

TABLE 5 Unit root test results

Variables	I(0)	I(1)	Decision
Yield	-4.0030 (0.0141)	-	I(0)

Area	-2.5318 (0.1137)	-8.6367 (0.0000)	I(1)
Production	-2.2909 (0.4316)	-13.0536 (0.0000)	I(1)

Note: The values shows the F statistic and values in parenthesis indicates the corresponding p values.

The stationarity test findings for the variables Yield, Area, and Production are shown in Table 5 according to their levels □(0) and I (1) to determine their order of integration. For time-series analysis, stationarity is essential, particularly in models like ARDL that can handle a combination of I(0) and I(1) variables.

TABLE 6 SHORT RUN RELATIONSHIP USING ARDL MODEL

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Yield (-1)	-0.06056	0.653722	-0.092633	0.9266
Yield (-2)	0.283566	0.120344	2.356298	0.0225
Area	1.119222	0.268109	4.174508	0.0001
Area (-1)	-1.598671	0.782254	-2.043672	0.0464
Production	0.629578	0.506973	1.241838	0.2202
Constant	624.5284	1050.890	0.594285	0.5551

The test appears to evaluate the short-run dynamics and relationships between area, production and yield of foodgrain in a time-series context.The first lag of yield in the short run (-1) has a coefficient of −0.06056, which does not show any significant relationship with the dependent variable yield (p value = 0.9266). On the other hand, the second lag (yield(−2)) has a positive and significant coefficient of 0.283566 (p-value = 0.0225), indicating that yield from two previous periods has a positive impact on the dependent variable.Current area (1.11921, p = 0.0001) positively affects the dependent variable yield, while the first lag of area (−1.5987,p = 0.0464) has a significant negative impact, suggesting immediate and delayed effects of area changes on foodgrain in India.The coefficient for production is 0.629578, indicating a positive relationship. However, the co-efficient is not statistically significant (p-value=0.2202). The constant term has a coefficient of 624.5284, but it is statistically not significant(p-value=0.5551).The analysis suggests that the dependent variable is significantly influenced by the factors such as the second lag of yield and the area (both current and lagged). Other variables, such as the first lag of yield, production, and the constant term, do not seemto influence yield levels.

TABLE 7 BOUND TEST

F STATISTIC	I (0)	I (1)
5.2703	3.1	3.87

The F-Bounds Test results evaluate the existence of a levels relationship (long-run equilibrium) among the variables in the model. The calculated F-statistic is 5.270279, which exceeds the critical value for the upper bound (I(1)) at the 5% significance level under both asymptotic (3.87) and finite sample (4.1) conditions. This suggests rejection of the null hypothesis of no levels relationship, indicating a statistically significant long-run relationship among the variables. The number of regressors (k) is 2, and the sample size used for the test is 55 observations.

TABLE 8 LONG RUN COEFFICIENT OF AREA, PRODUCTION ON YIELD OF FOODGRAIN IN INDIA

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Area	-0.617060	0.640464	-0.963458	0.3400
Production	0.810279	0.019512	41.526300	0.0000
Constand	803.7795	777.2344	1.034153	0.3061

Error Correction Equation: $EC = YIELD - (-0.6171 \cdot AREA + 0.8103 \cdot PDN + 803.7795)$

The coefficient for area is -0.6171, indicating aninverse relationship with the dependent variable yield. However, the t-statistic of -0.9635 and the probability (p-value) of 0.3400 suggest that this relationship is not statistically significant at conventional significance levels (e.g., 5% or 10%).The coefficient for production is 0.8103, and it statistically at o percent level, as evidenced by the very large t-statistic of 41.5263.This indicates that there is a strong positive association between production and yield. The constant term has a coefficient of 803.7795, with a t-statistic of 1.0342 and a p-value of 0.3061. This suggests that the constant term is not statistically significant at conventional levels, meaning it does not have a significant standalone contribution to the dependent variable yield.

The error correction equation (EC) derived from these coefficients is expressed as:

$EC = YIELD - (-0.6171 \cdot AREA + 0.8103 \cdot PDN + 803.7795)$

This equation indicates how the dependent variable yield adjusts based on deviations from the long-term equilibrium relationship involving area and production. Overall, while production significantly contributes to yield, the contribution of area and the constant term is not statistically significant in this model.

TABLE 9 ECM REGRESSION

The table 9 provides the results of an ECM (Error Correction Model) regression under the assumption of a restricted constant and no trend.

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
CointEq(-1)*	-0.776990	0.164272	-4.729883	0.0000

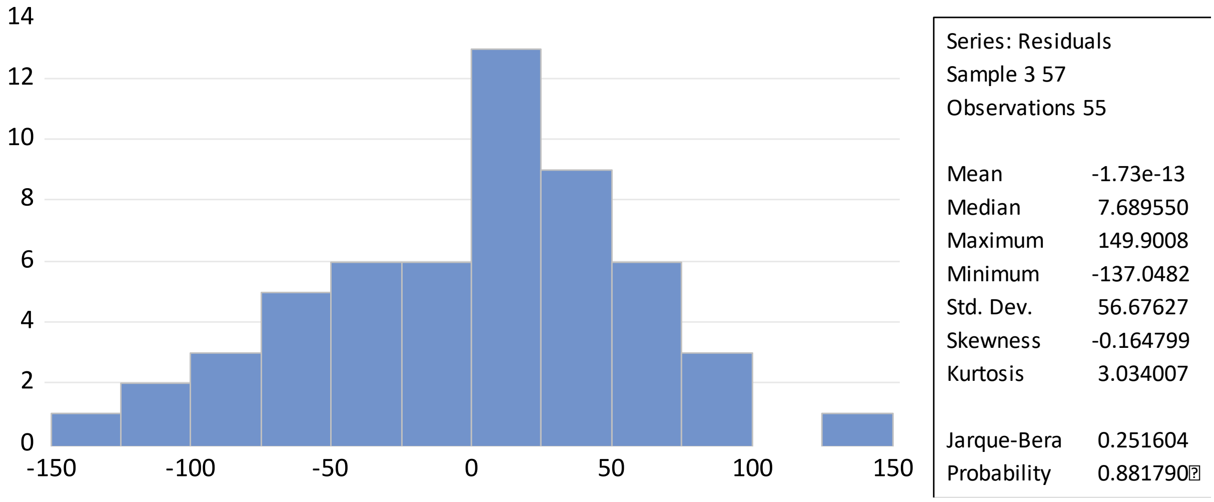
The coefficient of the error correction term is -0.7770, indicating the speed of adjustment toward equilibrium. A value close to -1 suggests a fast correction of deviations from the long-run equilibrium. The negative sign implies that any disequilibrium in the previous period is corrected in the current period. The high t-statistic (-4.730) and the p-value (0.0000) demonstrate strong significance, confirming the presence of a stable long-run relationship.

HISTOGRAM AND DESCRIPTIVE STATISTICS

The distribution and attributes of the model's errors are shown via the residuals' histogram and summary statistics.The histogram of residuals shows a bell-shaped pattern, suggesting that the errors are approximately normally distributed. This is supported by the statistical measures.

FIGURE 1

HISTOGRAM AND DESCRIPTIVE STATISTICS



An ideal characteristic for residuals in a well-defined model is that the mean of the residuals is nearly zero (-1.73e-13).The measured standard deviation of 56.67627 is consistent with some residual dispersion, as indicated by the median of 7.689550 and the maximum of 149.9008 versus the minimum of -137.0482.The measured standard deviation of 56.67627 is consistent with some residual dispersion, as indicated by the median of 7.689550 and the maximum of 149.9008 versus the minimum of -137.0482.The distribution has a small leftward asymmetry, as indicated by the skewness of -0.164799, which is near zero.There appears to be no obvious deviation from normal, as the kurtosis of 3.034007 is around the value of 3 for a normal distribution.The Jarque-Bera statistic is 0.251604, with a p-value of 0.881790. This high p-value indicates that the null hypothesis of normality cannot be rejected, further supporting the conclusion that the residuals are normally distributed.

The residual analysis suggests that the model is well-specified, with errors that are approximately normal, unbiased, and symmetrically distributed. This supports the validity of the model assumptions and implies that the results of the analysis are reliable. The normality of residuals also strengthens the credibility of hypothesis testing and inference based on the model.

Breusch-Godfrey Serial Correlation LM Test

The table 10 presents the results of the Breusch-Godfrey Serial Correlation LM Test, which tests for the presence of serial correlation in the residuals of the model up to two lags. The null hypothesis for this test is that there is no serial correlation in the residuals.

TABLE10 Breusch-Godfrey Serial Correlation LM Test

Statistic	Value	p-value
F-statistic	1.144170	0.3272
Obs*R-squared	2.553519	0.2789

The p value is greater than the significant value, we fail to reject the null hypothesis. This indicates no evidence of serial correlation at up to two lags.The Obs*R-squared value (2.553519) has a corresponding p-value of 0.2789. Similarly, this p-value exceeds common thresholds for significance, further supporting the conclusion that there is no serial correlation.The results of the Breusch-Godfrey test indicate that the residuals of the model do not exhibit serial correlation at up to two lags. This suggests that the model is correctly specified in terms of accounting for temporal dependencies, and no additional adjustments are necessary to address serial correlation. This is a positive indication of model reliability.

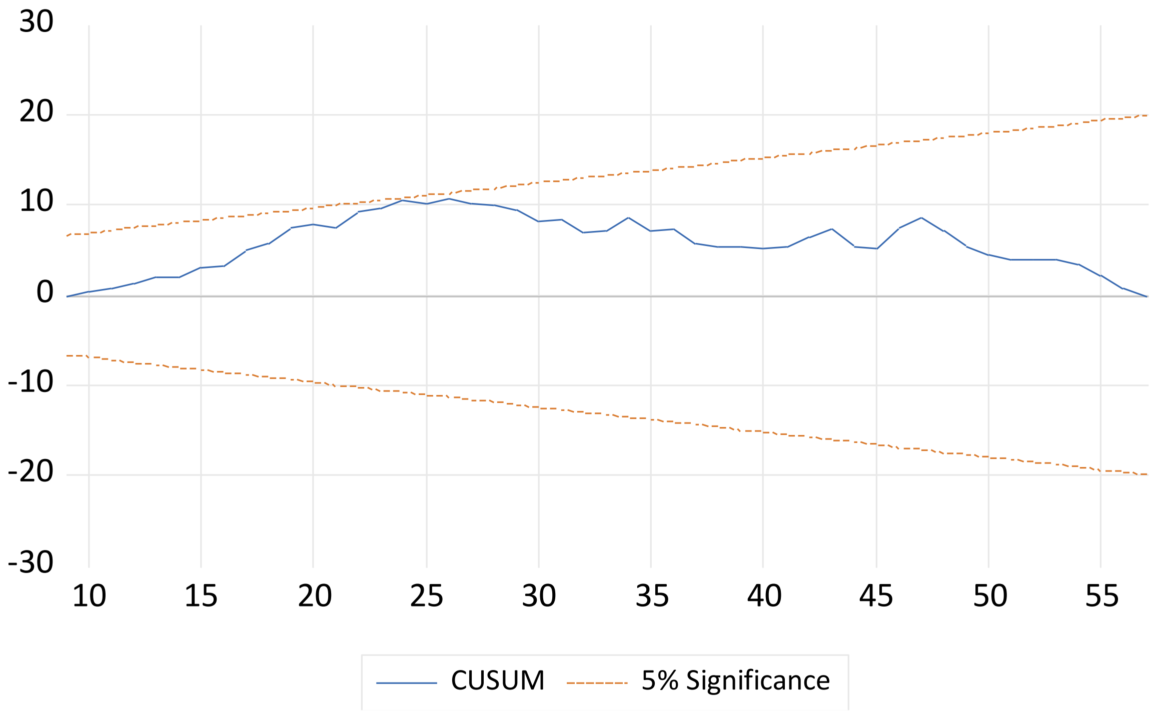
TABLE 11 HETEROSKEDASTICITY TEST

Test Statistic	Value	P-Value
F-statistic	0.753730	0.5874
Obs*R-squared	3.928011	0.5598
Scaled Explained SS	3.170750	0.6737

The Breusch-Pagan-Godfrey test for heteroskedasticity determines if a regression model's residual variance is constant, or homoskedastic. Homoskedasticity is assumed by the null hypothesis. The test findings show that the null hypothesis cannot be rejected, with an F-statistic of 0.753730 and a corresponding p-value of 0.5874. Likewise, the Scaled Explained SS statistic is 3.170750 with a p-value of 0.6737 and the Obs*R-squared statistic is 3.928011 with a p-value of 0.5598. There is no evidence to support the null hypothesis because all of these p-values are significantly higher than the usual significance level (e.g., 0.05). Thus, the findings imply that the homoskedasticity assumption is valid and that the model does not exhibit any appreciable heteroskedasticity.

FIGURE 2

CUSUM TEST

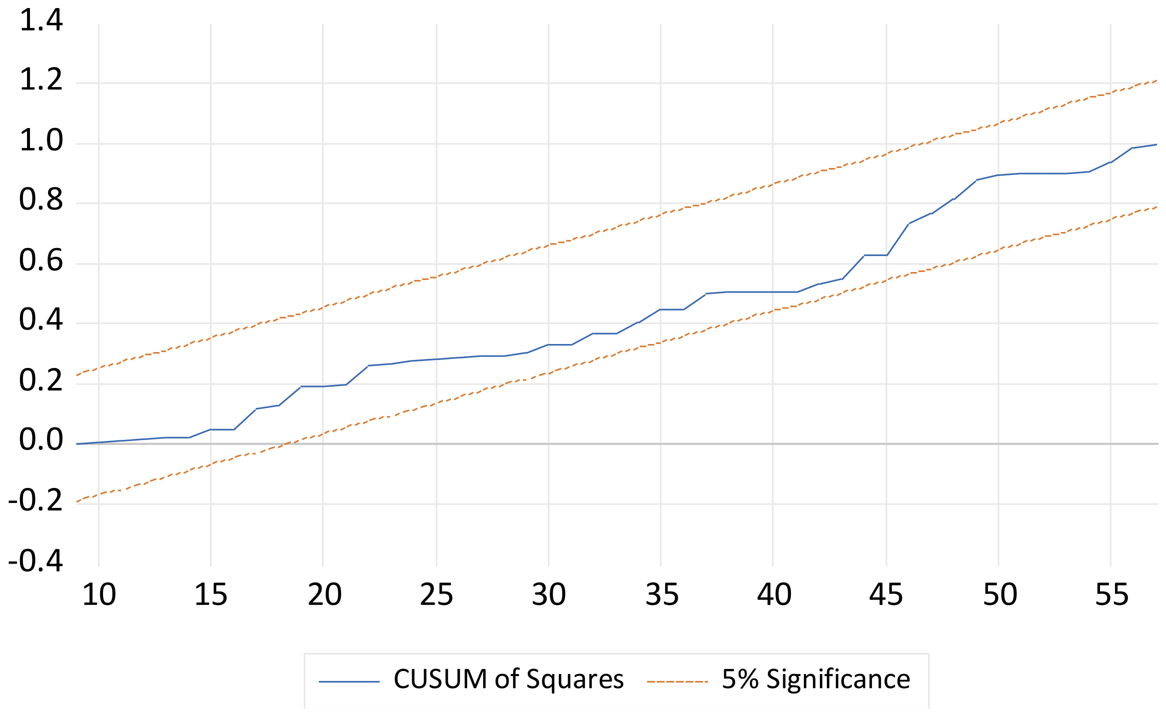


The Cumulative Sum (CUSUM) test, a diagnostic tool for evaluating the stability of regression model coefficients over time, is depicted in the graph. The orange dashed lines show the limits of the 5% significance level, while the blue line represents the CUSUM statistic. The model's coefficients appear to be stable across the observed period if the CUSUM statistic stays within the boundaries.There is no significant structural break or instability in the model, as shown by the CUSUM statistic in this graph, which remains well under the 5% significance bounds during the whole time period. This outcome validates the model's structural consistency and dependability over the given time frame. As a result, the stability of the coefficients strengthens the reliability of the regression results, confirming their use in inference and prediction.

FIGURE 3

CUSUM SQUARE TEST

A CUSUM of Squares (Cumulative Sum of Squares) test, which is often applied to assess a regression model's structural stability over time, is shown in the graph.



The model's structural stability is evaluated using the CUSUM of Squares test. Over the course of the observation period, the cumulative sum of squared residuals stays within the 5% significance bounds, as seen in Figure two. This confirms the model's reliability for the examined data by showing that it does not display structural instability or notable parameter shifts.

SIGNAL FLUCTUATIONS OVER TIME

A time series of residuals or deviations from a regression model seems to be displayed on the graph.Both positive and negative values on the line, which oscillates around zero, indicate deviations from the regression model's predicted values.The variations could be the result of unaccounted-for variations in the data or random errors. There is a visible spike in the graph's centre, indicating a notabledeviation there. This can point to a data structural change, an outlier, or a sudden shock. There appears to be no systematic bias in the residuals over time, since the series seems to return to a mean of zero. This shows that the model is fit.

FIGURE 4

SIGNAL FLUCTUATIONS OVER TIME

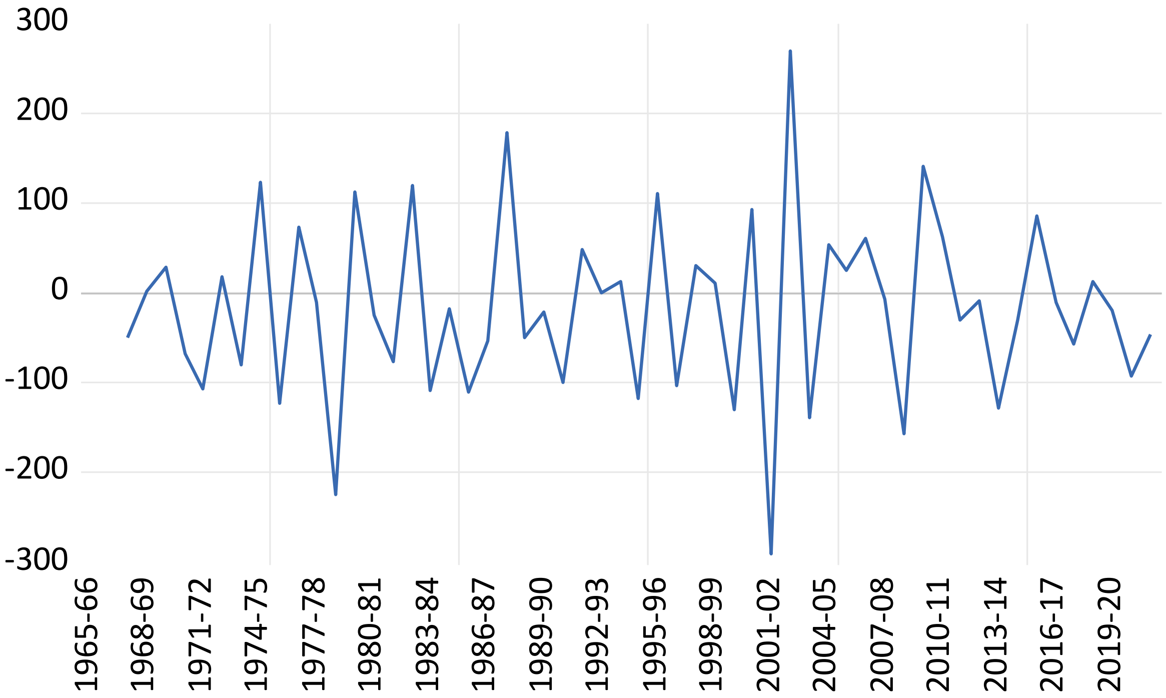


Figure 3 shows the residual time series, which shows how the observed values deviate from the model's predictions. The model does not show systematic bias, as indicated by the residuals' fluctuations about zero. A notable rise in the series' midpoint, however, points to a possible abnormality or shock in the data that might need more research. The pattern of the residuals indicates that the model functions well overall, showing no signs of persistent deviations or serial correlation.

Granger Causality Test

The table displays results from a Pairwise Granger Causality Test, which examines whether one time series can predict another.

TABLE 12 GRANGER CAUSALITY TEST

Null Hypothesis	Obs	F-Statistic	p-Value	Conclusion

AREA does not Granger Cause YIELD	55	0.5626	0.5733	No causality
YIELD does not Granger Cause AREA	55	0.2799	0.7570	No causality
PDN does not Granger Cause YIELD	55	0.6404	0.5314	No causality
YIELD does not Granger Cause PDN	55	184.418	8.E-24	Strong causality
PDN does not Granger Cause AREA	55	1.0903	0.3440	No causality
AREA does not Granger Cause PDN	55	39.4295	5.E-11	Strong causality

The Granger causality test results reveal significant predictive relationships between some variables while others show no evidence of causality. Specifically, yield of foodgrain Granger causes production with a highly significant F-statistic (184.418) and p-value (8.E-24), indicating a strong causal relationship. Similarly, area Granger causes Production of foodgrain, as evidentfrom a significant F-statistic (39.4295) and p-value (5.E-11). However, no Granger causality is observed between area and yield of foodgrain in either direction, nor does production of foodgrain Granger cause yield or area. These findings highlight specific directional influences, suggesting that yield and area of foodgrain are key predictors of production of foodgrain, but their interdependence with each other remains weak.

CONCLUSION

In the short-run analysis, a number of parameters, most notably the present and lagged area and the second lag of yield, have a substantial impact on foodgrain yield in India. Both the present and lagged areas exhibit significant effects, with the first lag of area having a negative influence and the second lag of yield having a positive huge impact. However, neither the constant term nor the production variable have a statistically significant impact on yield. Overall, the findings indicate that while production and the initial lag of yield have no discernible impact on the dependent variable, area and yield from prior periods are major drivers of foodgrain yield in India in the short-run. Where as in the long-run area and the constant term do not exhibit statistically significant effects, according to the data, but production significantly increases yield. The developed error correction equation illustrates how yield responds to adjusts from the production and area long-term equilibrium. In general, production is the primary factor that determines yield, while area and the constant term have negligible effects on the model.Strong causal relationships between area and production of foodgrain, as well as between yield and production, have been identified by the Granger causality test. However, there is no obvious causal relationship between production and yield or between area and yield. These findings imply that although yield and area are significant indicators of foodgrain production, there is still little correlation between them.

REFERENCE

1. Alimi, R. S. (2014). ARDL bounds testing approach to Cointegration: A re-examination of augmented fisher hypothesis in an open economy. *Asian Journal of Economic Modelling*, *2*(2), 103-114.

2. Breusch, T. S. (1978). Testing for autocorrelation in dynamic linear models. *Australian economic papers*, *17*(31).
3. Breusch, T. S., & Pagan, A. R. (1979). A simple test for heteroscedasticity and random coefficient variation. *Econometrica: Journal of the econometric society*, 1287-1294.
4. Brown, R. L., Durbin, J., & Evans, J. M. (1975). Techniques for testing the constancy of regression relationships over time. *Journal of the Royal Statistical Society Series B: Statistical Methodology*, *37*(2), 149-163.
5. Gadgil, S., Abrol, Y. P., & Rao, P. S. (1999). On growth and fluctuation of Indian foodgrain production. *Current Science*, 548-556.
6. Kumari, N., Mehta, V. P., & Bhatia, J. K. (2020). Foodgrains production in India: Trend and decompositions analysis. *Economic Affairs*, *65*(3), 333-342.
7. Pesaran, M. H., & Shin, Y. (1995). *An autoregressive distributed lag modelling approach to cointegration analysis* (Vol. 9514, pp. 371-413). Cambridge, UK: Department of Applied Economics, University of Cambridge.
8. Selvarajan, S., & Ravishankar, A. (1996). Foodgrain production and consumption in India: Shifts, trends and implications for food security. *Agricultural Economics Research Review*, *9*(2), 142-155.
9. Sharma, A. (2013). Trends of area, production and productivity of foodgrain in the north eastern states of India. *Indian journal of agricultural research*, *47*(4), 341-346.
10. Verma, S. R. (2006). Impact of agricultural mechanization on production, productivity, cropping intensity income generation and employment of labour. *Status of farm mechanization in India*, *2006*, 133-53.
11. Vijnana, A. (1997). Foodgrain production in India: a drive towards self-sufficiency. *Artha Vijnana*, *39*(2), 219-239.
12. Welfare, F. Ministry of Agriculture and Farmers Welfare (2022-23). *Government of India*.