NAVIGATING THE TRIAD: HOW AREA, YIELD, AND CREDIT SHAPE FOOD GRAIN PRODUCTION TRENDS IN INDIA

ARUSHI*
Lady Shri Ram College For Women, University of Delhi

Abstract

Agricultural development in India, as in many other developing countries, has long been recognised as a catalyst for the rapid growth of the overall economy. In the context of India's predominantly agrarian structure, understanding the dynamics of food grain production has been considered vital for ensuring food security, promoting rural prosperity, safeguarding the well-being of a large population, and advancing national development and economic stability. Drawing upon insights from existing literature, it had been identified that institutional credit, yield per hectare, and area under cultivation were significant determinants of food grain production in India. It had been established that an increase in cultivated area corresponded to higher potential for food grain output; that enhanced yield per hectare reflected improved efficiency and production; and that access to institutional credit enabled farmers to invest in improved agricultural inputs and practices, thereby augmenting yields.

The objective of the study had been to examine the effect of three explanatory variables—namely, area under cultivation of food grains, yield per hectare, and institutional credit for agriculture—on food grain production in India during the period 1966 to 2023. For this purpose, data had been obtained from a secondary source, specifically the Handbook of Statistics on the Indian Economy published by the Reserve Bank of India. The analysis had been conducted using R programming software, applying the Ordinary Least Squares (OLS) method. A multiple linear regression model had been constructed to explore the relationship between food grain production (dependent variable) and the three explanatory variables, and a simple linear regression model had been estimated to assess the direct relationship between food grain production and area under cultivation. The results obtained had been found to be statistically significant, indicating a positive association between food grain production and each of the three explanatory variables—area under cultivation, yield per hectare, and access to institutional credit—in the Indian context.

JEL Classification: E2, E6, Q1, Q5
Keywords: Agricultural economics; cultivation; food grain production; institutional credit; yield per hectare

1. INTRODUCTION

Agriculture has long been regarded as central to the Indian economy. It contributes approximately 14% to the nation's GDP and provides direct or indirect employment to nearly 45% of the population, as per recent estimates. A significant proportion of the labour force is engaged not only in agricultural activities but also indirectly in allied industries.

The sector plays a pivotal role in ensuring national food security and supplying essential raw materials to industries such as oil processing, sugar manufacturing, and textiles, including cotton. However, due to ongoing industrialisation, urbanisation, population growth, and the diversion of agricultural land for commercial purposes, the availability of arable land has been steadily declining. Furthermore, climate change is projected to pose

*Author's email address: arushigupta926@gmail.com

increasing risks to human health, employment opportunities, rural development, agri-based enterprises, food security, and farmer incomes in the near future. Numerous studies have reported that climate change has already produced adverse impacts on the agricultural sector, socio-economic activities, and the livelihood security of farming communities in India.

Agriculture also serves as the foundation for agro-based enterprises. Owing to its backward and forward linkages, it provides a substantial market for industrial goods and contributes significantly to the broader economy. Additionally, it supports agro-related services, thereby promoting the development of the tertiary sector. While international trade may supplement domestic agricultural supply, excessive dependence on food imports can undermine a nation's political autonomy, particularly during global disruptions. In light of the persistent food security challenges faced by many developing nations, food grain production remains a critical imperative.

Cereals and pulses constitute the two most essential components of the Indian diet. Rice and wheat are dietary staples for the vast majority of the population, while coarse cereals serve as a primary food source for lower-income groups. Pulses, being the most affordable source of protein, are an indispensable part of Indian meals. Enhancing agricultural output can be achieved either by expanding the area under cultivation or by improving agricultural productivity. During the initial phases of agricultural development, output had primarily been increased through extensive cultivation. Subsequently, growth has been driven by improvements in productivity, which have contributed to ensuring food security, enhancing farmer welfare, reducing rural poverty, mitigating rural-to-urban migration, lowering dependence on imports (particularly of pulses), and strengthening overall food resilience.

Agricultural productivity is commonly measured as the quantity of agricultural output per unit of input. At present, agriculture accounts for approximately 16.5% of India's GDP and continues to employ over 50% of the workforce. The Indian agriculture market is projected to grow from its 2022 valuation of USD 435.9 billion to USD 580.82 billion by 2028.

2. LITERATURE REVIEW

Food security has remained a critical concern for India, a country characterised by a vast population and a predominantly agricultural economy. Ensuring adequate foodgrain production has been closely linked to the need for maximising productivity.

2.1. Area Under Cultivation and Food Grain Productivity

The relationship between the area under cultivation and food grain production has been complex. Some studies have suggested a positive correlation. For instance, Minhas and Vaidyanathan (1965) observed that area expansion had significantly contributed to agricultural growth during the initial stages of India's development. Their findings aligned with the logic that bringing more cultivable land under production could directly increase overall output.

However, other scholars have cautioned against the limitations of this approach. Dasgupta (2001) argued that uncontrolled area expansion could lead to the cultivation of marginal lands, resulting in resource dilution and declining yields per hectare, which may ultimately negate productivity gains. Furthermore, environmental concerns such as deforestation and land degradation have often been associated with unregulated expansion.

Several studies have emphasised the importance of managing the quality of land brought under cultivation. Joshi and Jha (2009) highlighted the necessity of focusing on agriculturally suitable land with adequate irrigation potential in order to maximise the benefits of area expansion. Singh, Kumar, and Sharma (2020) argued that area expansion could be productive if coupled with technological advancements, such as precision irrigation and drought-resistant crop varieties. These innovations have enabled cultivation on previously marginal lands without significantly compromising yield levels.

2.2. Yield Per Hectare and Food Grain Productivity

Improving yield per hectare has been widely recognised as a critical strategy for enhancing food grain production without resorting to further expansion of cultivated land. Several interrelated factors have been found to contribute to yield enhancement.

2.2.1. Improved Seeds and Varieties

The introduction of high-yielding and disease-resistant crop varieties has significantly increased foodgrain production. Singh and Gupta (2017) credited the Green Revolution in India with achieving substantial improvements in yield through the widespread dissemination of improved wheat and rice varieties.

2.2.2. Enhanced Farming Practices

Advanced agronomic practices have played a vital role in optimising resource use and minimising crop losses. Lad, Verma, and Singh (2018) demonstrated the positive effects of precision agriculture, integrated pest management, and efficient irrigation on yield enhancement. These practices have enabled targeted input application, minimised wastage, and improved overall crop health.

2.2.3. Soil Health Management

Maintaining soil fertility has remained fundamental to achieving sustained improvements in yield. Verghese et al. (2010) emphasised practices such as crop rotation, composting, and the application of green manure, all of which help replenish soil nutrients and preserve long-term productivity.

2.2.4. Precision Farming

Lad, Sharma, and Chauhan (2021) documented the growing adoption of precision farming techniques in India. These methods employ sensor technology, data analytics, and site-specific input application to optimise resource use and maximise yields.

2.3. Institutional Credit for Agriculture and Food Grain Productivity

Access to institutional credit has been widely studied for its potential to empower farmers to make productivity-enhancing investments. Several studies have examined this linkage in detail.

2.3.1. Investment in Essential Inputs

Increased credit availability has allowed farmers to procure quality seeds, fertilisers, and pesticides. Das (2012) found a positive relationship between credit access and the use of high-quality agricultural inputs, which in turn led to improved crop health and higher yields.

2.3.2. Adoption of Modern Technology

Access to credit has facilitated investments in mechanisation, irrigation systems, and post-harvest infrastructure. Singh (2015) suggested that institutional credit had enabled the adoption of modern agricultural technologies, thereby improving resource use efficiency and reducing post-harvest losses—both of which have contributed to enhanced productivity.

2.3.3. Knowledge and Training

Credit availability has also supported farmers in obtaining training and technical knowledge. Joshi (2003) argued that institutional finance had helped farmers invest in capacity building, leading to better decision-making and more effective utilisation of resources, which ultimately enhanced yields.

2.3.4. Direct Benefit Transfer Schemes

Recent research by Chand, Saxena, and Rana (2020) evaluated the role of Direct Benefit Transfer (DBT) schemes in agricultural credit delivery. While DBT has aimed to improve transparency and reduce leakages in credit disbursal, the study highlighted challenges related to limited farmer awareness and accessibility, which have constrained its potential positive impact on agricultural productivity.

3. RESEARCH OBJECTIVE

The objective of this research paper is to identify and establish the effects of selected explanatory variables—namely, the area under cultivation of food grains (measured in lakh hectares), yield per hectare (measured in kilogrammes per hectare), and institutional credit for agriculture (comprising loans disbursed by Co-operatives, Scheduled Commercial Banks, and Regional Rural Banks, each measured in Rs crores)—on food grain production in India.

Drawing upon findings from existing literature and guided by the author's own expectations, the study aims to test the hypothesis that a positive relationship exists between food grain production and each of the specified explanatory variables.

4. DATA AND METHODOLOGY

The investigation utilised a dataset on agricultural production of food grains in India, comprising both cereals (rice, wheat, and coarse cereals) and pulses, spanning the period from 1966 to 2023. These data were obtained from a secondary source—the Handbook of Statistics on the Indian Economy, published by the Reserve Bank of India and accessed via its official website. In addition, an extensive review of scholarly literature had been conducted to inform the selection of variables and support the methodological framework adopted for the regression analysis.

The analysis commenced with the estimation of a two-variable linear regression model to examine the individual effect of the area under cultivation of food grains on total food grain production. Hypothesis testing was employed to assess the statistical significance of the relationship between the explanatory and dependent variables. Subsequently, a multivariable regression model was developed to evaluate the joint influence of the three independent variables—area under cultivation, yield per hectare, and institutional credit—on food grain production, using the F-test for overall model significance. Both models were estimated in RStudio using the Ordinary Least Squares (OLS) method.

Prior to interpreting the regression results, diagnostic checks were conducted to ensure that the Classical Linear Regression Model (CLRM) assumptions were satisfied. The direction and significance of slope coefficients were examined to determine consistency with established economic theory. The mean value of the error term was verified through an analysis of residuals from the multiple linear regression model. The Durbin-Watson test was used to test forautocorrelation, while the presence of multicollinearity was assessed using the correlation matrix and scatterplots of the independent variables. The normality of residuals was evaluated through the histogram and the Jarque-Bera test. Lastly, the White test was conducted to identify any presence of heteroskedasticity. The adjusted R-squared value was also analysed to assess the proportion of variance in the dependent variable explained by the model.

5. HYPOTHESIS

Model 1: 2-Variable Simple Linear Regression Model

A priori expectation of intercept and slope coefficient (α_1) for model 1:

$$\text{Ho: } \alpha_1 = 0 \text{ Ho: } \alpha_0 = 0$$

$$\text{Ha: } \alpha_1 > 0 \text{ Ha: } \alpha_0 \neq 0 \qquad (1)$$

Against the null hypothesis of statistical insignificance, dwelling on past research, literature review and the authors' expectations, the testing for statistical significance of α0is done by a 2-tailed test and α1is done by an upper tail test. This follows the a priori expectation that increased area under cultivation will lead to a positive increase in overall foodgrain production. This assumes sufficient resources and infrastructure are available to effectively cultivate the expanded area.

Model 2: Multivariable Linear Regression Model

The joint hypothesis developed for this model is stated as follows:

$$\text{Ho: } \beta_1 = \beta_2 = \beta_3 = 0 \text{ OR } R^2 = 0 \qquad (2)$$

$$\text{Ha: } \beta_1, \beta_2 \text{ and } \beta_3 \text{ are not simultaneously equal to zero OR } R^2 > 0$$

Against the null hypothesis of statistical insignificance and based on the stated econometric theory, the testing for the joint hypothesis has been done with the help of the F-test for statistical significance. This follows the a priori expectation that the explanatory variables, the area under cultivation, yield per hectare and institutional credit for agriculture and allied activities have a significant impact on the dependent variable, and their individual effects should not simultaneously be equal
to zero.

6. ANALYSIS AND RESULTS

6.1. Descriptive Statistics

From the descriptive statistics, it may be observed that, on average, agricultural production of food grains stood at approximately 1,803 lakh tonnes, the area under cultivation was 1,242 lakh hectares, average yield per hectare was 1,451 kilogrammes, and institutional credit for agriculture averaged Rs. 2,20,627 crores over the study period. It is important to note that the credit values used in this analysis are expressed in nominal terms. While this reflects the actual disbursement figures over time, the use of inflation-adjusted (real) values would provide a more precise representation of credit growth and its real impact. However, due to the unavailability of a consistent and long-term deflator series specific to agricultural credit for the period 1966 to 2023, the analysis has been necessarily conducted using nominal figures. The relatively high standard deviations across all four variables indicate considerable dispersion in the data.

Furthermore, time-series analysis revealed that between 1966–67 and 2022–23, India's food grain production increased from approximately 1,268 million tonnes to 3,305 million tonnes, reflecting a cumulative growth of 161% and a compound annual growth rate (CAGR) of 1.65% per annum. The area under cultivation expanded modestly, from 115.3 million hectares to 132.2 million hectares (a growth of 14.7%, a CAGR of 0.22% per annum). In contrast, yield per hectare nearly doubled during the same period, rising from around 1,100 kg/ha to 2,500 kg/ha (a 127% increase, a CAGR of 1.29% per annum). These figures indicate that improvements in agricultural productivity, rather than land expansion, have been the principal driver of food grain production growth in India.

Although detailed year-wise institutional credit data from the RBI Handbook are limited, secondary literature suggests that real-term credit disbursements increased substantially, particularly during the period 2001–02 to 2010–11, coinciding with notable gains in agricultural productivity.

To comprehensively assess this dimension, future research should endeavour to compile annual nominal credit series for the entire period and adjust these using appropriate deflators (such as CPI or WPI) to estimate real-term credit growth and its implications.

Table 6.1.1

Statistic	Agricultural Production of Food Grains (lakh tonnes)	Area under cultivation of Food Grains (lakh hectares)	Yield Per Hectare of Food Grains (kg/hectare)	Institutional Credit for Agriculture and Allied Activities (Rs. crores)
Min	742	1139	644	327
1st Quartile	1296	1220	1022	4169
Median	1795	1239	1491	14636
Mean	1803	1242	1451	220627
3rd Quartile	2177	1268	1777	192233
Max	3107	1312	2394	1575398
Variance	377394.4	1172.952	238564.2	165361873956
Standard Deviation	614.324	34.24	488.430	406647.112

Source: RBI Handbook

6.2. Model Specification

First, a two-variable linear regression was conducted to ascertain the relationship between agricultural production of food grains and the area under cultivation of food grains. The model was specified as follows:

$$Y_i = \alpha_0 + \alpha_1 X_{1i} + u_i \quad (3)$$

- Y_i represents the agricultural production of food grains in an observation i, measured in lakh tonnes.
- X_{1i} denotes the area under cultivation of food grains in observation , measured in lakh hectares.
- α_0 and α_1 represent the intercept and the slope coefficient, respectively.
- u_i is the error term.

Further, to investigate the relationship between the agricultural production of food grains (dependent variable) and two additional independent variables: yield per hectare and institutional credit for agriculture, a multiple linear regression model was constructed which is specified as follows:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + u_i \quad (4)$$

- Y_i represents the agricultural production of food grains in an observation i, measured in lakh tonnes.
- X_{2i} denotes the yield per hectare of food grains in observation i, in kilogrammes.
- X_{3i} represents the institutional credit for agriculture and allied activities in observation I, in rupees crores.
- β_0, β_1, β_2, and β_3 represent the intercept and partial slope coefficients of the independent variables, respectively.
- u_i is the error term.

Table 6.3.1

Variable	Estimate	Standard Error	t-Statistic	p-Value
Intercept (α_0)	−2108.924	3013.165	−0.700	0.487
Area under Cultivation (α_1)	3.150	2.426	1.299	0.200

Note: Dependent variable: food grain production (lakh tonnes); area in lakh hectares. Estimated using OLS in R Studio
Source: RBI Handbook

Table 6.3.2

Statistic	Value
Residual Standard Error	610.5
Degrees of Freedom	53
Multiple R-Squared	0.03085
Adjusted R-Squared	0.01256
F-Statistic (1, 53 df)	1.687
p-value	0.1996

Note: Model demonstrates low explanatory power.
Source: Author's calculations based on RBI data

6.3. Regression Results

The results for the two-variable regression model (model 1) are presented in Tables 6.3.1 & 6.3.2. The coefficients α_0 and α_1 represent the intercept and the slope, respectively. In this model, both coefficients are found to be statistically insignificant at the 5% level, as indicated by their corresponding p-values. Consequently, the null hypothesis (H_0) cannot be rejected. This suggests that area under cultivation alone does not significantly explain variations in food grain production during the study period. The multivariable regression (model 2) results are presented in Tables 6.3.3 & 6.3.4. The F-statistic is significant for model 2 at 5% level of significance; thus, the joint H_0 stated previously will be rejected. The regression coefficients indicate the extent of the relationship between the independent variables and the agricultural production of food grains. The significance levels and signs of the coefficients provide insights into the direction and strength of these relationships. the agricultural production of food grains. The significance levels and signs of the coefficients provide insights into the direction and strength of these relationships.

Table 6.3.3

Variable	Estimate	Standard Error	t-Statistic	p-Value
Intercept (β_0)	-1552.000	79.380	-19.551	< 2e–16***
Area under Cultivation (β_1)	1.270	0.06291	20.179	< 2e–16***
Yield per Hectare (β_2)	1.220	0.00680	179.502	< 2e–16***
Institutional Credit (β_3)	0.00003807	0.00000834	4.563	< 3.21e–05***

Note: 1. Yield in kg/hectare; Area under cultivation in lakh hectares; Institutional credit in Rs crores (nominal);. Estimated using OLS in RStudio
*2. Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*
Source: RBI Handbook and Author's calculations

Table 6.3.4

Statistic	Value
Residual Standard Error	610.5
Degrees of Freedom	53
Multiple R-Squared	0.03085
Adjusted R-Squared	0.01256
F-Statistic (1, 53 df)	1.687
p-value	0.1996

Source: Author's computation

6.4. Model Fit and Interpretation

The results ascertained after running the regression pave the way forward to analyse the same with the motive of dealing with the research questions and hypotheses that have been posed in this paper. The interpretation of the coefficients involves assessing the impact of each independent variable on agricultural production of food grains while holding other variables constant, which can be summarised as follows:

Model 1: Simple 2-Variable Linear Regression Model

$$\hat{Y}_i = -2108.924 + 3.150X_{1i} + \varepsilon_i \quad (5)$$

- The intercept for the 2-variable regression model (a_0) can be interpreted in the sense that the mean predicted agricultural production of food grains is -2108.924 when the area under cultivation is equal to zero. However, this interpretation holds no economic significance, as production can never be negative, even if the area under cultivation is zero.
- The value of the coefficient (a_1) is equal to 3.15. This suggests that for a one lakh hectare increase in the area under cultivation for food grains, the estimated mean production of food grains increases by 3.15 lakh tonnes, ceteris paribus. There exists a positive relationship between the 2 variables which is economically and logically consistent.
- To begin with the hypothesis testing for the intercept (a_0), the p-value>0.05; thus, the intercept is not statistically significant. Similarly, the p-value for the slope coefficient>0.05 which indicates that the slope coefficient is also not statistically significant at 5% level of significance. Thus, H_0 cannot be rejected for model 1.
- Thus, model 1 does not give statistically significant results, and there appears to be a specification error committed in constructing the model.

$$\hat{Y}_i = -1552 + 1.270X_{1i} + 1.220X_{2i} + 0.00003807X_{3i} + \varepsilon_i \quad (6)$$

- The intercept for the multivariable regression model (b_0) holds a value of -1552, which indicates that the mean predicted agricultural production of food grains is -1552 lakh tonnes when the values of all the explanatory variables are taken as 0. Similar to Model 1, this interpretation is inconsistent, as it does not hold any economic significance.
- The values of the coefficients b_1, b_2 and b_3 are positive and can be interpreted as follows: b_1= 1.270, which reflects the fact that, keeping other explanatory variables constant, a one lakh hectare increase in the area under cultivation for food grains leads to a mean predicted increase in the production of food grains by 1.27 lakh tonnes.

Similarly, the values of b_2=1.220 and b_3=0.00003807 will lead to a mean predicted increase in production of 1.22 and 0.00003807 lakh tonnes when X_3 and X_4 increase by 1 unit, respectively, keeping all other variables constant.

- The results for the Joint Hypothesis can be acquired using Table 6.3.4. The analysis for the joint hypothesis requires the F statistic to be greater than F critical to conclude that the three independent variables are jointly significant in having an impact on the dependent variable. Here, the F statistic is 29030, which is greater than the F critical, which is 2.79, computed using F tables. Therefore, the F value is statistically significant, implying that all 3 explanatory variables are jointly significant and have an impact on the dependent variable. Thus, the null hypothesis defined earlier will be rejected.

6.5. R^2 values and the F test statistic

The overall goodness of fit of the estimated models was evaluated using the R^2 statistic, which quantifies the proportion of variance in the dependent variable that is explained by the independent variables. For Model 1, the computed R^2 value was 0.03085, indicating that only 3.05% of the variation in food grain production was explained by the area under cultivation alone. This low value suggested a weak explanatory power for the simple regression model.

In contrast, Model 2 yielded an R^2 value of 0.994, implying that approximately 99.4% of the variance in food grain production was explained by the three explanatory variables—area under cultivation, yield per hectare, and institutional credit. This substantial increase in explanatory power underscored the importance of including all relevant variables in the regression specification.

The statistical significance of Model 2 was further assessed using the F-test, which resulted in an F-statistic of 29,030. This considerably large value provided strong evidence against the null hypothesis that no relationship exists between the dependent and independent variables, thereby confirming the joint significance of the explanatory variables. The comparison of the two models indicates that Model 1 suffered from a specification error due to the omission of key explanatory variables. When these variables were incorporated into Model 2, the regression output showed statistically significant coefficients and a markedly improved goodness of fit, as reflected in the rise of the adjusted R^2 from 0.01256 in Model 1 to 0.994 in Model 2. Additionally, the absolute values of the t-statistics exceeded unity for both the intercept and the slope coefficients in the multivariable model, further supporting the model's robustness. Thus, the shortcomings in Model 1 were effectively addressed through the expanded specification of Model 2.

6.6. Robustness Check

In order to assess the reliability of the estimated multivariable regression model (Model 2), a set of diagnostic procedures was undertaken to examine the validity of the Classical Linear Regression Model (CLRM) assumptions.

- The assumption of linearity in parameters was met based on the structural specification of the model.
- The condition of zero mean of the error term was verified through residual analysis, which confirmed that the average residual is approximately zero.
- The normality of residuals was examined using the Jarque-Bera test, supplemented by visual assessments such as the histogram and normal probability plot. Both approaches supported the normality assumption.
- Autocorrelation was tested using the Durbin-Watson statistic, which indicated the absence of statistically significant autocorrelation at the 5% level.
- Homoscedasticity was assessed through the White test, the results of which indicated the presence of heteroskedasticity (p-value < 0.05). Attempts were made to address this by exploring alternative functional forms, including lin-log and log-log specifications; however, these did not yield improved model performance. This limitation is duly acknowledged.

Given that the dataset employed in this study spans a time series from 1966 to 2023, the use of Ordinary Least Squares (OLS) warrants additional diagnostic checks that are specific to time-series econometric analysis—most notably, stationarity testing. The

The presence of non-stationary variables can potentially lead to spurious regression outcomes, wherein apparently strong relationships, as indicated by high R-squared values, may be misleading. Although the analysis incorporates checks for autocorrelation, normality, and heteroskedasticity, it does not, at present, include formal stationarity tests such as the Augmented Dickey-Fuller (ADF) or KPSS tests. This is primarily due to the limited scope and data standardisation challenges encountered during the course of this undergraduate research. The author fully recognises this as an important limitation and recommends that future extensions of this work incorporate such procedures. Where necessary, the adoption of time-series-specific models, such as the Autoregressive Distributed Lag (ARDL) framework, Vector Autoregression (VAR), or Error Correction Models (ECM), would enhance the robustness and validity of the empirical findings.

Conclusively, while several key assumptions of the classical regression model have been satisfied, certain limitations inherent to time-series data remain. These have been transparently acknowledged, and it is hoped that future research can build upon the present analysis with more advanced econometric tools and a broader data framework.

The findings of the tests for these assumptions are presented in the appendix elaborately.

7. LIMITATIONS AND SCOPE

The econometric models employed in this study are subject to certain limitations, which are outlined below.

First, evidence of low to moderate multicollinearity was observed among the explanatory variables in Model 2. This indicates a potential linear relationship between some of the independent variables, as substantiated by the scatter plots presented in the appendix.

Second, the presence of heteroskedasticity was detected in the model, as indicated by a p-value less than 0.05 in the White test. While this issue was acknowledged, attempts to address it through alternative functional specifications, such as lin-log and log-log transformations, did not yield improved model performance. These attempts and their results are detailed in the appendix.

Third, the variable representing institutional credit for agriculture and allied activities was not disaggregated by crop type and, therefore, is not specific to food grains. This limitation arises from constraints in the availability of granular credit data at the national level.

Fourth, although the dataset spans the period from 1966 to 2023, the model was estimated by treating the data as cross-sectional rather than time-series or panel data. This approach was adopted due to the scope and level of the current study, although it is acknowledged that time-series methods are more commonly applied in similar empirical research.

Fifth, while diagnostic checks such as the Durbin-Watson, Jarque-Bera, and White tests were conducted, formal testing for stationarity, a critical assumption for time-series analysis, was not performed. Tests such as the Augmented Dickey-Fuller (ADF) or KPSS were excluded from the current scope, and future studies may benefit from their inclusion to ensure that the estimated relationships are not spurious.

Sixth, the institutional credit data used in this study were expressed in nominal terms. Although this accurately captures the disbursed amounts, the absence of inflation-adjusted (real) credit values due to the non-availability of a consistent long-term deflator may obscure the true purchasing power and real growth impact of credit over time.

Despite these limitations, it may be concluded that the model satisfies the major assumptions of the Classical Linear Regression Model (CLRM). While violations of certain assumptions were identified, these do not invalidate the results but rather highlight areas where future research may adopt advanced remedial techniques as outlined in econometric literature.

8. POLICY IMPLICATIONS

The empirical results of this study establish that food grain production in India is greatly influenced by area under cultivation and yield per hectare, together with access to institutional credit. Given these results combined with perspectives taken from past research, we offer the policy suggestions below.

8.1. Prioritisation of Yield Enhancement Measures

The results do indicate that yield per hectare has improved and has principally driven growth in food grain production, as opposed to cultivated area then expanding. Agricultural policy consequently should stress easing the dissemination of high-yielding, drought-resistant crop varieties. Agronomic methods research alongside agricultural extension systems requires reinforcement from agricultural policy. Substantial productivity gains resulted in part from adopting improved crop varieties plus farming techniques, as was demonstrated by Singh and Gupta (2017) and Lad et al. (2018). Furthermore, Lad, Sharma, and Chauhan (2021) noted that we should promote precision farming technologies. We should incentivise these technologies also through targeted public investment and training programmes.

8.2. Reform and Targeting of Institutional Credit

Institutional credit has emerged as an important factor in agricultural output in this study. However, the data used were only available in nominal terms. This limits the ability to assess the real purchasing power of credit over time. Future policy plans should focus on collecting and using inflation-adjusted (real) credit data to improve credit planning. Additionally, to improve credit delivery, administrative barriers should be reduced. Special attention must also be given to making credit more accessible for small and marginal farmers, especially women. This aligns with the findings of Das (2012), Singh (2015), and Chand, Saxena, and Rana (2020). They highlighted the role of credit in helping adopt modern agricultural technologies and practices.

8.3. Strategic Land Use Planning

While the area under cultivation continues to positively relate to production, the small gains from expanding land are limited. Joshi and Jha (2009), along with Singh, Kumar, and Sharma (2020), suggest a more strategic approach to land use is needed. Policy should focus on bringing underused but fertile land into cultivation. This should be supported by sufficient irrigation infrastructure and informed by spatial data technologies like GIS and satellite imagery.

8.4. Strengthening Agricultural Data Systems

The challenges faced in this study, especially the lack of detailed and inflation-adjusted credit data, highlight the need to strengthen India's agricultural data systems. Creating a national repository of standardised, crop-specific, and regionally detailed datasets would allow for better modelling, targeted policy design, and more accurate impact assessments.

8.5. Integrated Climate Resilience and Post-Harvest Management

With Indian agriculture becoming more vulnerable to climate change, policies must encourage climate-resilient farming practices. Interventions should include better water management, improved soil health, and support for agroecological practices (Verghese et al., 2010; Pathak, 2022). Additionally, investing in post-harvest infrastructure, such as storage, transportation, and value addition, is crucial to reduce losses and ensure stable farmer incomes.

These policy directions illustrate the complex nature of food grain production and the need for a coordinated approach that combines productivity improvement, financial access, land-use efficiency, data transparency, and environmental sustainability.

9. CONCLUSION

The findings of this study confirm that the area under cultivation, yield per hectare, and access to institutional credit each have a statistically significant and positive influence on food grain production in India. While the expansion of cultivated areas continues to contribute to output growth, improvements in yield—driven by technological innovation, efficient resource use, and modern agronomic practices—are likely to play an increasingly central role in enhancing agricultural productivity.

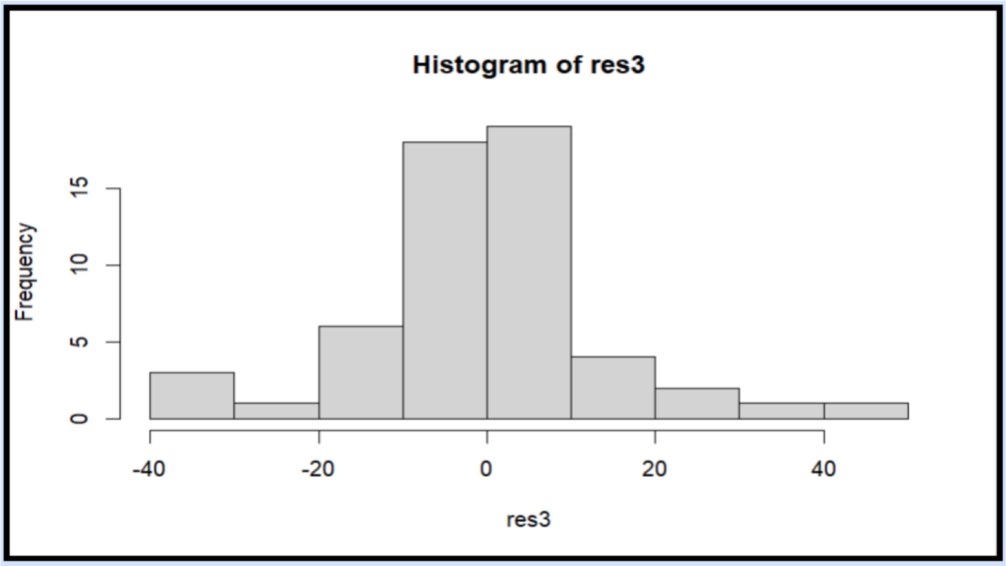
Institutional credit remains an essential enabler of such productivity gains. Accordingly, public policies and institutional frameworks should focus on improving credit accessibility, particularly for marginal and women farmers, thereby empowering them to adopt modern inputs and technologies.

Additionally, challenges such as climate variability, soil degradation, and post-harvest losses must be addressed through sustained policy attention strategy is therefore necessary to strengthen food grain production and ensure long-term food security in India.

By integrating recent empirical findings with long-term trends, this study contributes to a more comprehensive understanding of the determinants of food grain productivity in India and offers policy-relevant insights for agricultural development.

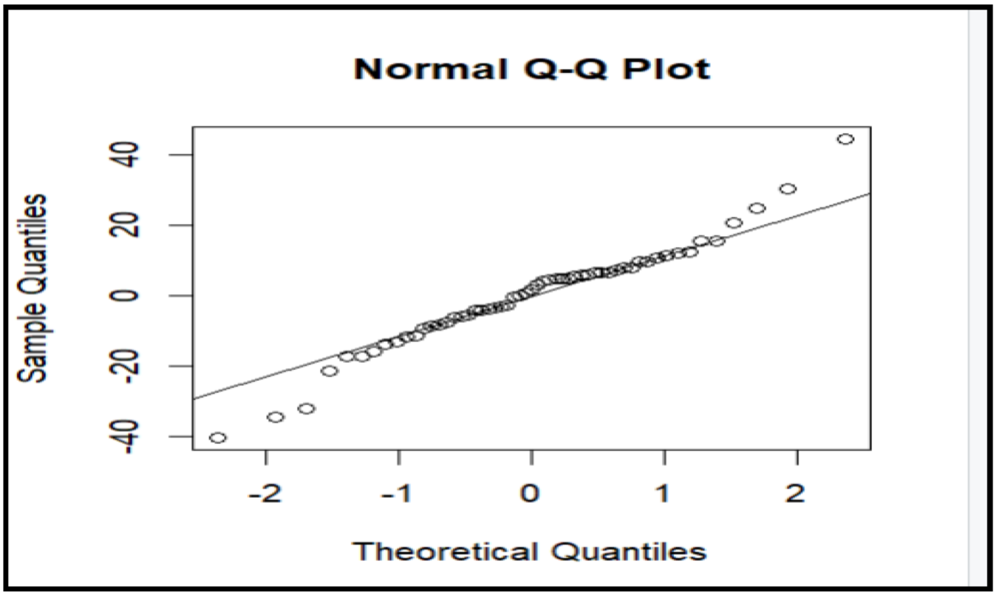
APPENDIX

Figure A1: *Histogram showing the normality of residuals for the multivariable regression model*



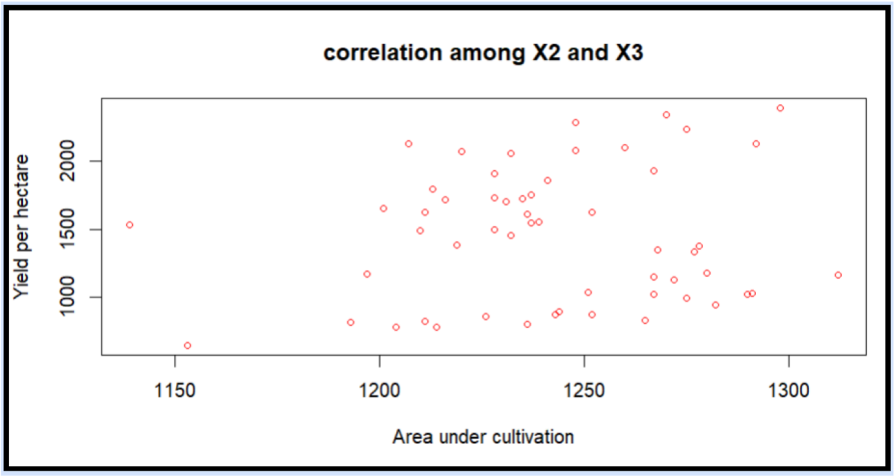
Source: Author's calculations

Figure A2: *Normal probability plot for residuals*



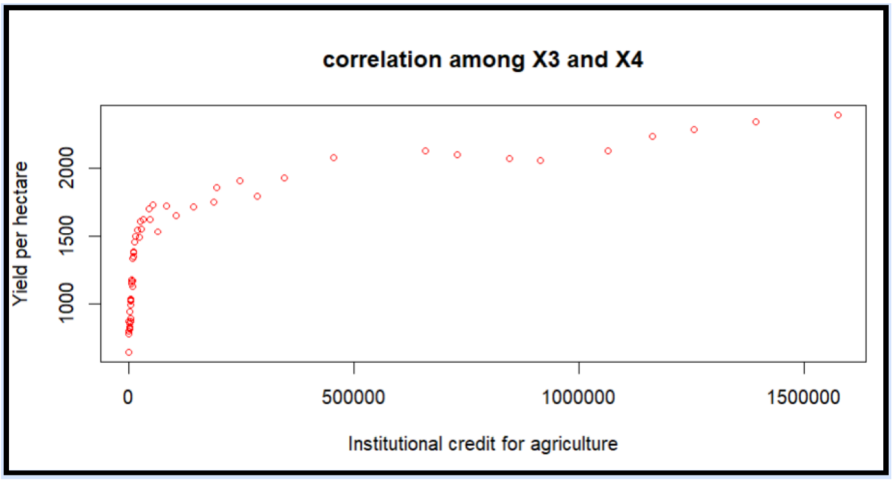
Source: Author's calculations

Figure A3: *Scatterplot with yield per hectare and area under cultivation on the Y and X axes, respectively*



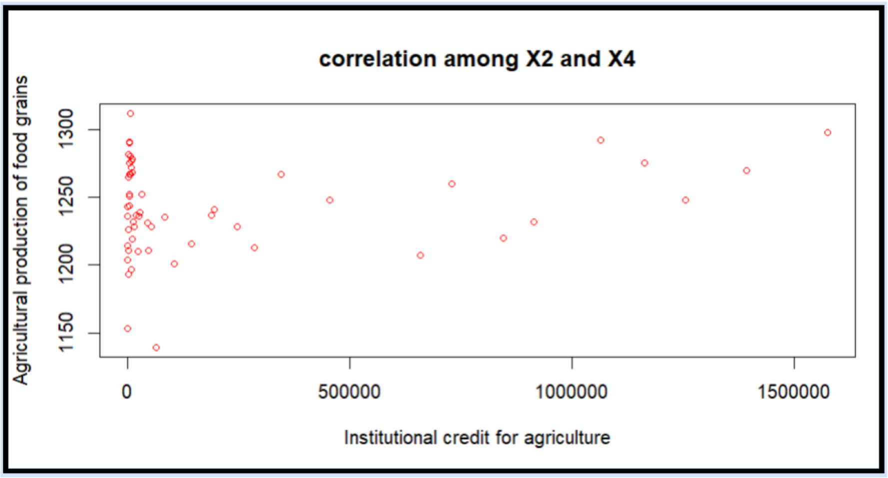
Source: Author's calculations

Figure A4: *Scatterplot with yield per hectare and institutional credit for agriculture on the Y and X axes, respectively*



Source: Author's calculations

Figure A5: *Scatter Plot with agricultural production of foodgrains and institutional credit for agriculture on the Y and X axes, respectively*



Source: Author's calculations

Table A1: *Summary of the residuals for model 2 (Mean value of the error term = 0)*

Statistic	Min	1st Qu.	Median	Mean	3rd Qu.	Max
Value	-40.440	-7.948	1.840	0.000	7.436	44.475

Source: Author's calculations

Table A2: *Durbin-Watson Test for Autocorrelation (Model 2)*

Lag	Autocorrelation	D-W Statistic	p-value
1	**0.03533447**	**1.686746**	**0.098**

Source: Author's calculations
Note: Alternative hypothesis: ρ≠0

Table A3: *Results of the White test for heteroskedasticity (Model 2)*

Statistic	p-value	Parameter	Method	Alternative
27.2	0.000135	6	White's Test	greater

Source: Author's calculations

REFERENCES

1. Bardhan, Pranab K. "Size, Productivity, and Returns to Scale: An Analysis of Farm-Level Data in Indian Agriculture." *The University of Chicago Press Journals*, Vol. 81. https://doi.org/10.1086/260132

2. Base, G. L. "Agricultural Productivity in India." *LinkedIn Pulse*, November 15, 2023

3. Chand, Ramesh, Ritu Saxena, and Suresh Rana. "Impact of Direct Benefit Transfer Schemes on Agricultural Productivity in India." *Economic and Political Weekly* 55, no. 8 (2020): 34–41. https://aeraindia.in/upload/16238157725331.pdf

4. Das, Abhijit. "Credit and Agricultural Productivity: A Case Study of Indian Agriculture." *Journal of Rural Development* 31, no. 3 (2012): 281–298. https://www.researchgate.net/publication/348779271_Agricultural_credit_and_agricultural_productivity_across_Indian_states_An_analysis

5. Dasgupta, Partha. "Human Well-Being and the Natural Environment." *Oxford: Oxford University Press*, 2001.

6. Dasgupta, S. "Land Use Changes and Agricultural Productivity in India." *Indian Journal of Agricultural Economics* 56, no. 2(2001): 234–245. https://www.researchgate.net/publication/227365225_Agricultural_Productivity_Trends_in_India_Sustainability_Issues

7. Hatfield, J. L., B. A. Kimball, A. M. Thomson, and D. Wolfe. "Climate Impacts on Agriculture: Implications for Crop Production." March 2011. https://acsess.onlinelibrary.wiley.com/doi/abs/10.2134/agronj2010.0303

8. Joshi, P. K., and D. Jha. "Managing Land and Water Resources for Sustainable Agriculture." *Agricultural Systems 101*, no. 1 (2009): 40–50. https://www.researchgate.net/publication/329144556_Land_Resources_and_their_Management_for_Sustainability_in_Arid_Regions

9. Joshi, P. K. "Strengthening Agricultural Technology Dissemination through Institutional Partnership-Based Extension Model." 2003. https://epubs.icar.org.in/index.php/IJAgS/article/download/104333/40825/340343

10. Joshi, Suresh. "The Role of Institutional Credit in Promoting Agricultural Development." *Journal of Development Economics* 45, no. 3 (2003): 563–578

11. Lad, P., A. Verma, and N. Singh. "Enhancing Yield Per Hectare: A Study of Precision Agriculture Techniques." *International Journal of Agricultural Science* 12, no. 2 (2018): 145–153.

12. Lad, P., R. Sharma, and A. Chauhan. "Adoption of Precision Farming in India: Challenges and Opportunities." *Journal of Precision Agriculture* 14, no. 4 (2021): 321–338.

13. Minhas, B. S., and A. Vaidyanathan. "Growth of Crop Output in India 1951–54 to 1958–61: An Analysis by Component Elements." *Indian Journal of Agricultural Economics* 20, no. 1 (1965): 1–21.

14. Pathak, H. "Impact, Adaptation, and Mitigation of Climate Change in Indian Agriculture." November 2022.

15. Reserve Bank of India. Handbook of Statistics on the Indian Economy.

16. Sati, Vishwambhar Prasad. "The Future of Food and Agriculture in India: Trends and Challenges." June 2023.

17. Shah, Deepak. "Foodgrain Production in India: A Drive Towards Self-Sufficiency." June 1997.

18. Singh, Ajay K. "Projected Food-Grain Production and Yield in India: An Evidence from State-Wise Panel Data Investigation during 1977–2014." January 2021.

19. Singh, Anil Kumar. "Pulses Production in India: Present Status, Bottlenecks and Way Forward." ICAR 2, no. 2 (2015).

20. Singh, P., Kumar, and R. K. Sharma. "Development of Informative Genic SSR Markers for Genetic Diversity Analysis of Picrorhiza kurroa." *Journal of Plant Biochemistry and Biotechnology 2020*.