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Research paper

A Study on The Impact of The Green Revolution on Agricultural Output and Its Role in Supporting Sustainable Agriculture in India

Arun R [1], Siva Kumar S [2]*

[1] Ph.D (IFT) Research Scholar, Department of Social Sciences, School of Social Sciences and Languages, Vellore Institute of Technology (VIT), Vellore. Pincode:632014
[2] Associate Professor, Department of Social Sciences, School of Social Sciences and Languages, Vellore Institute of Technology (VIT), Vellore. Pincode:632014
**Corresponding author E-mail: siva.kumars@vit.ac.in*

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Abstract

India is one of the world's largest agrarian economies and agricultural commodity producers. However, the country's ability to meet domestic food demand continues to lag behind its expanding population. The gap between population increases and food grain production is large. To overcome this issue and avoid food scarcity, current technology and tactics must be implemented. The Green Revolution, a new agricultural policy launched in 1965, aimed to enhance rice and wheat production and thereby reduce hunger and poverty. This study investigates the long-term effects of Green Revolution tactics on agricultural productivity and production in India. The paper analyzes the influence of these strategies on wheat and rice production and productivity using secondary data from credible sources, as well as statistical and econometric tools. The findings of the study show that the annual growth rate of the population began to decline after 1971, with a compound annual growth rate of 18.29 Percent. The annual growth rate of food grain output fluctuates, and the compound annual growth rate has been 25.42 percent across the years.

Keywords: *Green Revolution; Technology; Wheat; Paddy Production; Productivity.*

1. Introduction

Agriculture has always played a crucial role in the Indian economy, employing approximately 54.6% of cultivators (Census, 2011). The primary sector contributes around 17% to the national GDP and continues to be a key driver of employment, both directly and indirectly, providing livelihoods for about 70% of rural households. The agriculture sector accounts for nearly 18% of the country's GDP and engages more than 60–70% of the Indian population (K.M. Arjun, 2013). The sector's contribution to national Gross Value Added (GVA) increased from 17.8% in 2019–20 to 19.9% in 2020–21 (Ministry of Statistics and Programme Implementation, 2021). According to Singh et al. (2014), about 22.8% of cultivators use modern seeds, while 50% of major farmers adopt scientific production methods. Interestingly, small farmers achieve higher yields and net earnings than large farmers when using High-Yielding Variety Seeds (HYVS). They also incur lower overall costs and are more efficient in rice cultivation (Thangamayan & Thirunavukkarasu, 2019). Recognizing the growing challenge of meeting the country's rising food grain demand, policymakers introduced a new strategy to maximize agricultural production and productivity. This marked the beginning of the Green Revolution in 1965, which brought a transformative change to India's agricultural sector. Dr. M. S. Swaminathan, a distinguished Indian scientist, is credited with spearheading this initiative. By 2050, the global population is projected to exceed 9 billion, which is expected to increase food demand by up to 102% (Wang, 2022; Fukase, 2020). In this context, India's policymakers are aiming to double farmers' incomes and make agriculture self-sustaining within the national economy. Over the last few decades, Indian agriculture has proven its resilience as a growth engine, with food grain production rising from 51 million metric tons in 1950–51 to 330.5 million metric tons in 2021–22 (Down to Earth, 2023). The critical question, however, is whether modern agricultural technologies and techniques will be sufficient to meet the growing demand for food grains while ensuring sustainability. Can they also contribute to achieving long-term development goals such as zero hunger, poverty reduction, and sustained economic growth? To address these questions, this study assesses the impact of the new agricultural strategy on food grain production, with a particular focus on rice and wheat production and productivity. The central objective is to examine how Green Revolution practices have influenced wheat and paddy output in India in the broader context of sustainable development.

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2. Review of Literature

During the Green Revolution, the introduction of High-Yielding Varieties (HYVs) significantly increased cereal production, particularly wheat and rice. India's food grain production doubled between 1965 and 1990 (Evenson & Gollin, 2003). The effectiveness of Green Revolution technologies turned regions such as Punjab and Haryana into food grain surplus areas (Gulati & Fan, 2007). A technological assessment of the Green Revolution (Pingali, 2012) noted that wheat yields more than tripled between 1965 and 1995, largely due to high-yield seed varieties and strong policy support. However, the benefits of the Green Revolution were uneven. Increased irrigation and infrastructure development favored certain regions, leading to disparities in food production (Bhalla & Singh, 2009). Rainfed and eastern regions were largely neglected, resulting in stagnant yield growth (Rosegrant & Hazell, 2000). The Green Revolution also faced criticism for promoting chemical-intensive farming, which caused soil degradation, biodiversity loss, and depletion of groundwater resources (Shiva, 1991). Although it generated short-term productivity gains, the overuse of fertilizers and pesticides has been linked to long-term environmental damage (Tilman et al., 2002). Sustainability challenges are particularly evident in the Indo-Gangetic Plains, where groundwater over-extraction and soil salinization are widespread (Kumar & Joshi, 2016). Socioeconomic inequalities also emerged. Unequal access to technology and capital widened the gap between large and small farmers (Frankel, 1971). Sociocultural consequences included rising rural inequality and tenancy issues in high-productivity areas (Bardhan, 1984). These concerns led to calls for a "Second Green Revolution," one that balances increased output with environmental sustainability, especially in eastern and rain-fed regions (Rao, 2005). To address these challenges, strategies such as conservation agriculture, organic inputs, and precision farming have been promoted as pathways toward sustainable intensification (ICAR, 2017). Overall, the Green Revolution had far-reaching socioeconomic impacts, reshaping rural livelihoods, income distribution, and agricultural market dynamics (Hazell, 2009; Krishna, 2010).

3. Methods

3.1 Research problem

Crops are widely acknowledged as playing a vital role in a country's economic development. The production and productivity of agricultural products determine the livelihoods of millions of people, especially in countries with large populations and significant economic and social disparities in terms of income and affordability, such as India. To feed the growing population, the government's primary responsibility is to ensure an adequate food supply. In this context, studying the impact of the Green Revolution on the adoption of modern agricultural technologies becomes critical to understanding the level of output and yield of food grain crops in the country.

3.2 Research gap

Many early studies on Indian agriculture focused on aspects such as production, cultivated area, and the overall impact of the Green Revolution. However, no specific study has thoroughly examined the effect of modern agricultural technologies, introduced under the Green Revolution, on the production and productivity of key crops such as wheat and rice in the context of sustainability. This study seeks to fill that gap.

3.3 Study area

This research assesses the impact of new agrotechnologies implemented in India during the 1960s under the Green Revolution. The study area covers the country's total geographical area of 3,287,263 square Kilometers, of which 9% is surrounded by water and 91% is land. As a predominantly agrarian economy, India had about 203.18 lakh hectares under crop cultivation as of June 2013 (Ministry of Agriculture and Farmers' Welfare, 2023).

3.4. Study period

The present study focuses on the impact of the Green Revolution on the output and yield of primary crops, particularly wheat and rice. For this purpose, secondary data was collected from reliable sources covering eight decades (1950–51 to 2020–21). The chosen time frame allows for analysis both before and after the introduction of Green Revolution techniques in the 1960s, thereby providing a comprehensive understanding of their impact on crop output and yield.

3.5. Data source and data analysis

The study relies on secondary data collected from reliable government sources. Statistical and econometric tools were applied in this research. The Compound Annual Growth Rate (CAGR) was used to analyse the growth of output over time, and the Student's t-test was employed to determine whether there is a statistically significant difference between the mean output of wheat and rice.

4. Result

India has the largest population in the world, and its size poses a major concern for the growing economy. The pressing question is whether the country will be able to feed all its people if the current population growth rate continues. Is the present rate of food grain production sufficient to meet this challenge? If not, what measures should be taken to address it? These questions form the basis of the present research analysis.

Table 1: Population Size in India (in Millions)

Year	Population Size	Annual growth rate
1951	361.1	-
1961	439.2	21.63
1971	548.2	24.82
1981	683.3	24.64

1991	846.4	23.87
2001	1028.7	21.54
2011	1210.19	17.64
2021	1393.40	15.14
CAGR	18.39%	

Source: Economic Survey, 2021-2022.

According to Table 1, India's population was 361.10 million in 1951 and rose to 1,393.40 million in 2021, marking an increase of 285.88 percent over the study period. The compound annual growth rate of the population during this period was 18.39 percent. However, the annual growth rate began to decline after 1971, largely due to government initiatives to control population growth and increased public awareness of the one-child policy or the two-child policy for a healthier and more comfortable life.

Table 2: Food Grain Production (in Million Tons)

Year	Food grain production	Annual Growth Rate
1951	50.80	-
1961	82.02	61.46
1971	108.42	32.18
1981	129.59	19.53
1991	176.39	36.11
2001	196.80	11.57
2011	244.49	24.23
2021	311.00	27.20
CAGR	25.42%	

Source: Times of India, 2022.

Table 2 shows that food grain output in India was 50.8 million tons in 1951 and increased to 311 million tons in 2021, reflecting a growth of 512 percent over the study period. India has made remarkable progress in food grain production and continues to be ranked as the second-largest producer of several food grains. Although output has fluctuated from year to year, the compound annual growth rate (CAGR) remains at 25.42 percent, which is higher than the country's population growth rate.

According to the Second Advance Estimates for 2022–23, the country's total food grain production is expected to reach a record 3,235.54 lakh tonnes (Ministry of Agriculture and Farmers' Welfare, 2023). This remarkable achievement in crop production has been made possible through the adoption of modern technologies in Indian agriculture. There is substantial evidence that technological advancements have had a significant long-term impact on agricultural production (Chumki Handique, 2020).

Table 3: Production of Wheat and Rice in India (in Million Tons)

Year	Wheat	Rice
1950-51	6	20
1960-61	11	34
1970-71	23	42
1980-81	36	53
1990-91	55	74
2000-01	69	84
2010-11	86	95
2020-21	109	122
2021-22	104	129
2022-23	110	135
2023-24	113	137
2024- 25	117	149

Source: Agricultural Statistics at a glance, 2022, and Annual Report 2024,2025, Ministry of Agriculture and Farmers Welfare.

Table 3 presents the output trends of wheat and rice from 1950–51 to 2024–25. Wheat production, which was 6 million tons in 1950–51, is projected to rise to 113 million tons by 2024–25, reflecting a dramatic increase over the study period. Similarly, rice production increased from 20 million tons in 1950–51 to 149 million tons by 2024–25, marking another remarkable achievement. These trends highlight the country's significant progress in food grain production, particularly after the implementation of the revolutionary agricultural strategy known as the Green Revolution.

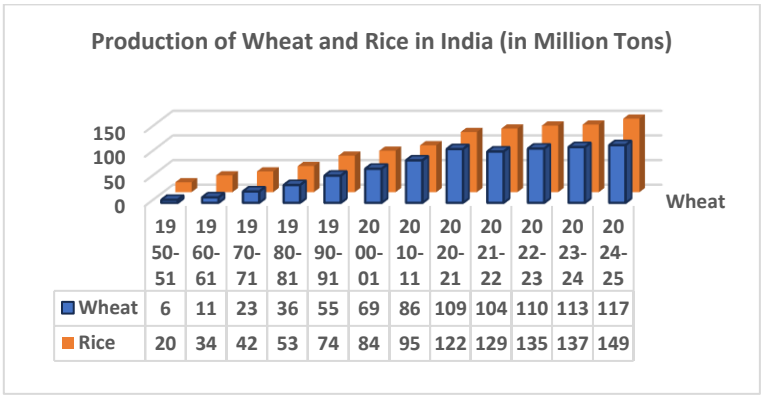

Fig 1: Production of Wheat and Rice in India (in Million Tons).

The above line diagram clearly shows an upward trend for both variables, despite fluctuations in their values. To examine the association, the following hypothesis was proposed.
Ho: The adoption of Green Revolution techniques has not yielded a statistically significant difference between the average production levels of wheat and rice.

Table 4: Student's t-test Result Relating to Production of Wheat and Rice

	Wheat	Rice
Mean	69.91666667	89.5
Variance	1796.265152	2025.727273
Observations	12	12
Pooled Variance	1910.996212	
Hypothesized Mean Difference	0	
Df	22	
t Stat	-1.097317558	
P(T<=t) one-tail	0.142184208	
t Critical one-tailed	1.717144374	
P(T<=t) two-tail	0.284368416	
t Critical two-tailed	2.073873068	

Source: Student's t-test Result.

The Student's t-test was applied to determine whether there is a significant difference between the average production of wheat and rice. The results reveal that the computed p-value is 0.28, which is greater than the 5% level of significance (0.05). Therefore, we do not reject the null hypothesis. This indicates that there is no substantial difference in the average production of wheat and rice after the introduction of the Green Revolution in the 1960s. The Green Revolution techniques appear to have had nearly the same effect on both wheat and rice production.

Table 5: Productivity of Wheat and Rice in India (in Kilograms Per Hectare)

Year	Wheat	Rice
1950-51	655	668
1960-61	851	1013
1970-71	872	1123
1980-81	1630	1336
1990-91	2281	1740
2000-01	2708	1901
2010-11	2988	2239
2020-21	3521	2713
2021-22	3177.51	2798
2022-23	3521	2838
2023-24	3559	2882
2024-25	3587	2899

Source: Agricultural Statistics at a glance, 2022, and Annual Report 2024,2025, Ministry of Agriculture and Farmers Welfare.

Table 5 highlights the significance of land productivity per hectare for two major crops, wheat and rice, before and after the implementation of Green Revolution techniques. The variables were analyzed over the period 1950–51 to 2024–25. During this time, the productivity of both crops increased substantially. Wheat yields rose from 655 kg per hectare in 1950–51 to 3,587 kg per hectare in 2024–25, while rice yields increased from 668 kg per hectare to 2,899 kg per hectare over the same period. This remarkable achievement underscores the critical role of the Green Revolution in enhancing agricultural productivity in India.

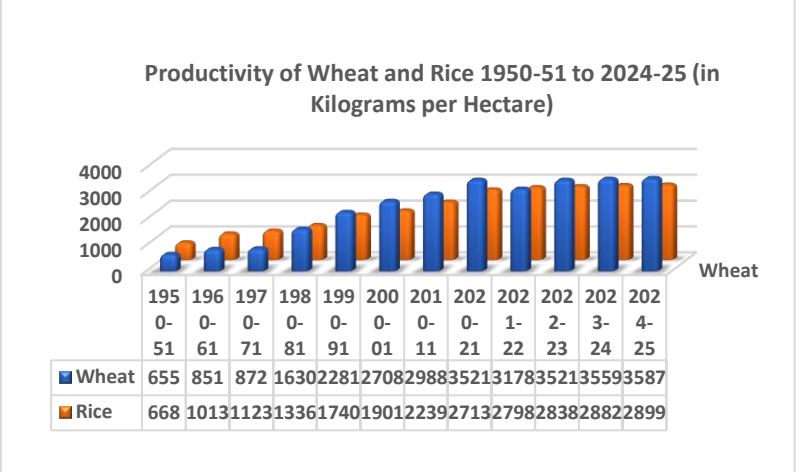

Fig. 2: Productivity of Wheat and Rice in India (in Kilograms Per Hectare).

Figure 2 illustrates the relationship between rice and wheat productivity over the years. Both have shown a steady increase over time. To further examine this relationship, the following hypothesis has been formulated.
Ho: The adoption of Green Revolution techniques has not yielded a statistically significant difference between the average productivity of wheat and rice.

Table 6: Student's t-test Result Relating to the Land Productivity of Wheat and Rice

	Wheat	Rice
Mean	2445.875833	2012.5
Variance	1333788.881	684055.1818
Observations	12	12
Pooled Variance	1008922.032	
Hypothesized Mean Difference	0	
Df	22	
t Stat	1.056845523	
P(T<=t) one-tail	0.151024853	
t Critical one-tailed	1.717144374	
P(T<=t) two-tail	0.302049705	
t Critical two-tailed	2.073873068	

Source: Student's t-test Result.

The Student's t-test was applied to determine whether there is a significant difference between the average productivity of wheat and rice. The results reveal that the computed p-value is 0.30, which is greater than the 5% level of significance (0.05). Therefore, we do not reject the null hypothesis. This means that the adoption of the revolutionary agricultural technique named the green revolution has not produced much difference in both wheat and rice productivity per hectare of land. The deployment of the green revolution technique has achieved extraordinary results, particularly with the implementation of the country's significant plan. Wheat and rice productivity have both increased significantly. The production and productivity of wheat and rice have created an outstanding record over the other cereals, and again, rice productivity has overtaken wheat productivity in the country (Mudakappa, 2019).

5. Discussion

The Green Revolution has been regarded as a successful strategy for increasing food grain output in India, making substantial contributions toward achieving Sustainable Development Goals (SDGs) such as zero hunger and poverty alleviation through enhanced food grain production and productivity. As a result, the production of staple crops such as wheat and rice increased dramatically, particularly after the introduction of this technology. For instance, wheat production rose from 6 million tonnes in 1950–51 to 113 million tonnes in 2023–24, while rice production grew from 20 million tonnes to 137 million tonnes over the same period.

According to a study by Krishna Gowda (2024), sugarcane production increased more than sevenfold compared to wheat and rice between 1950–51 and 2021–22. Similarly, Bibin Prabu (2021) reported that wheat production grew by 3.6 percent and rice production by 3.2 percent between 2007 and 2008. A comparable analysis by Yudhisther Singh and Pallavi Ghosh (2022) showed that the net cultivated area for rice and wheat expanded from 30.81 and 9.75 million hectares in 1950 to 43.95 and 31.19 million hectares in 2014. Consequently, per capita net availability of rice and wheat increased from 50.8 and 24 kg per year in 1950 to 69.3 and 70.1 kg per year in 2017. The Ministry of Agriculture and Farmers' Welfare (2001) reported that total rice and wheat output rose significantly from 39.4 and 11.3 million tonnes in 1966 to 89 and 76 million tonnes in 2000. According to Pingali (2012), the Green Revolution had a greater impact on wheat than rice, with wheat production in states such as Punjab and Haryana rising substantially due to better irrigation infrastructure.

In terms of productivity, both wheat and rice registered substantial gains after the adoption of Green Revolution practices. Wheat productivity increased from 655 kg per hectare in 1950–51 to 3,177.51 kg per hectare in 2020–21, while rice productivity grew from 668 kg per hectare to 2,798 kg per hectare during the same period. Krishna Gowda (2024) noted that wheat achieved the highest productivity among major crops, rising from 350 kg per hectare in 1950–51 to 2021–22. Internationally, Japan recorded the highest rice productivity (7,161 kg per hectare), while Germany led in wheat productivity (7,819 kg per hectare), both surpassing India during the same period. Prashant Kumar (2017) observed that the R8 rice variety achieved yields of 10 tonnes per hectare after the Green Revolution, compared to 5 tonnes per hectare earlier. Between 1960 and 1990, rice yields tripled per hectare.

Given the challenge of meeting the country's aggregate food grain demand as well as export requirements, it is critical to modernize India's agricultural system. In this regard, the following measures are suggested to enhance sustainability and productivity:

1) Improve irrigation infrastructure: Existing irrigation routes and water sources should be streamlined and made accessible to farmers nationwide. Interlinking rivers and constructing a national river network is recommended.
2) Ensure affordable agricultural inputs: Inputs such as seeds, fertilizers, and pesticides must be made affordable and easily available, as current prices remain too high for many small farmers to cover variable costs.
3) Protect agricultural land: Legislation should be introduced to safeguard farmland, ensuring it is used exclusively for cultivation and not diverted for non-agricultural purposes.
4) Adopt farmer-friendly policies: Policies should prevent forced sales of cultivable land for real estate development, which reduces agricultural activity and threatens food security.

6. Conclusion

Despite the Government of India's significant efforts and initiatives, achieving the Sustainable Development Goals (SDGs) of zero poverty and zero hunger remains a major challenge. The contribution of all sectors must be strengthened to ensure holistic national progress, as economic growth cannot be driven by the performance of a single sector alone, in line with the SDG framework. The agricultural sector continues to play a vital role and is consistently emphasized in development policies. Although rice and wheat production have shown remarkable improvement since the implementation of the Green Revolution, much remains to be done to fully meet the food requirements of both domestic and global populations. Countries with substantial land resources, such as India, bear a greater responsibility in ensuring food security while advancing toward the SDGs. However, India still has considerable ground to cover before it can achieve complete alignment with these goals. This study highlights multiple perspectives and challenges related to agricultural development. Future researchers may extend the analysis by examining the impact of Green Revolution techniques on other major crops beyond rice and wheat.

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Author Contributions

This article is the outcome of collaborative academic work between the research scholar and the supervisor. Arun R - Conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing-original draft preparation; Siva Kumar S – writing-review and editing, supervision.

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Data Availability Statement

The dataset generated and analyzed during the current study is available from the corresponding author upon reasonable request.

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