



Revisiting the Green Revolution in India: Assessing Achievements, Challenges, and Future Prospects

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Abstract

The word "Green Revolution" was coined by William S. Gaud of United States Agency for International Development (USAID) in 1968, for the introduction of new technology and policies implemented in the developing nations with aids from industrialized nations between the 1940s and the 1960s to increase the production and yield of food crops. Many high-yielding varieties (HYVs) were introduced as part of the Green Revolution to increase agricultural productivity [1].

The Green Revolution in India, initiated in the late 1960s, marked a significant turning point in the country's agricultural landscape, aiming to boost food production and alleviate poverty. Decades later, as India grapples with issues of sustainability, food security, and environmental degradation, there is a critical need to revisit the Green Revolution's impact and legacy.

This article provides a comprehensive analysis of the Green Revolution's achievements, challenges, and future prospects in India. It explores the historical context and the driving forces behind the Green Revolution, examining its impact on agricultural productivity, rural livelihoods, and socio-economic dynamics.

Despite its initial success in increasing food production and alleviating hunger, the Green Revolution also brought forth a range of challenges. Issues such as environmental degradation, soil fertility depletion, water scarcity, and socio-economic disparities have emerged as significant concerns, casting a shadow on the sustainability of the Green Revolution model.

Furthermore, the article discusses the contemporary relevance of the Green Revolution in the context of shifting global dynamics, technological advancements, and climate change. It underscores the need for a holistic approach towards agricultural development that integrates principles of sustainability, equity, and resilience.

Drawing on lessons learned from the past and insights from current research, the article proposes strategies to revitalize India's agricultural sector while addressing the shortcomings of the Green Revolution paradigm. These include promoting agroecological approaches, investing in rural infrastructure, enhancing farmer resilience, and fostering inclusive policies that prioritize the needs of smallholder farmers and marginalized communities.

In conclusion, the article advocates for a nuanced understanding of the Green Revolution's legacy and calls for a renewed commitment to sustainable agricultural development in India. By leveraging innovation, technology, and participatory approaches, India can chart a path towards food security, environmental stewardship, and inclusive growth in the 21st century.

Keywords: Climate Change; Green Revolution; HYV Seeds; India; Irrigation

Introduction

The Green Revolution stands as a watershed moment in India's agricultural history, heralding a transformative era of increased productivity, food security, and economic growth. Initiated in the late 1960s, this movement aimed to address the pressing challenges of food scarcity and poverty through the adoption of high-yielding crop varieties, modern farming techniques, and extensive use of agrochemical inputs.

Decades later, as India navigates the complexities of a rapidly evolving agricultural landscape characterized by environmental degradation, climate change, and socio-economic disparities, there is a compelling need to revisit the Green Revolution's legacy. This introduction sets the stage for a comprehensive exploration of the achievements, challenges, and future prospects of the Green Revolution in India.

In this article, we embark on a journey to critically examine the impact of the Green Revolution on India's agricultural sector, rural communities, and broader socio-economic fabric. We delve into the historical context that gave rise to this agricultural revolution, tracing its evolution and examining the driving forces behind its implementation.

Moreover, we scrutinize the multifaceted outcomes of the Green Revolution, from its undeniable success in boosting agricultural productivity and ensuring food security to the nuanced challenges it has engendered, including environmental degradation, soil erosion, and socio-economic inequalities. By shedding light on both the triumphs and tribulations of this paradigmatic shift in Indian agriculture, we seek to foster a nuanced understanding of its implications for sustainable development.

Furthermore, this introduction sets the stage for a forward-looking discussion on the contemporary relevance of the Green Revolution in the face of evolving global dynamics, technological advancements, and climate change. We explore how India can leverage the lessons learned from the Green Revolution era to chart a path towards a more sustainable, equitable, and resilient agricultural future.

In conclusion, this introduction serves as a preamble to a holistic analysis of the Green Revolution in India, offering insights into its historical significance, present-day challenges, and future trajectories. By engaging with this complex and multifaceted phenomenon, we endeavor to contribute to ongoing dialogues on agricultural development, sustainability, and inclusive growth in India and beyond.

Objectives of the Study

- Assess the historical context and driving forces behind the initiation of the Green Revolution in India, providing a comprehensive understanding of its inception and implementation.
- Evaluate the impact of the Green Revolution on key indicators of agricultural productivity, including crop yields, land use patterns, and farm incomes, to gauge its effectiveness in addressing food scarcity and poverty alleviation.
- Examine the socio-economic implications of the Green Revolution, analyzing its effects on rural livelihoods, income distribution, and social dynamics, with a focus on marginalized communities and smallholder farmers.
- Investigate the environmental consequences of the Green Revolution, including soil degradation, water depletion, and biodiversity loss, to understand the trade-offs associated with intensive agricultural practices.
- Identify the challenges and limitations of the Green Revolution paradigm, such as sustainability concerns, input dependency, and socio-economic disparities, to inform future agricultural policies and interventions.
- Explore the contemporary relevance of the Green Revolution in the context of shifting global dynamics, technological advancements, and climate change, highlighting opportunities for innovation and adaptation.
- Propose strategies and recommendations for revitalizing India's agricultural sector while addressing the shortcomings of the Green Revolution model, with a focus on promoting sustainability, equity, and resilience.
- Foster dialogue and knowledge exchange among policymakers, researchers, practitioners, and stakeholders to facilitate informed decision-making and collective action towards sustainable agricultural development in India.

Methodology

This article depends upon secondary data drawn from books and journals.

Review of Literature

- The Green Revolution in India was initiated in the 1960s by introducing high-yielding varieties of rice and wheat to increase food production in order to alleviate hunger and poverty. Post-Green Revolution, the production of wheat and rice doubled due to initiatives of the government, but the production of other food crops such as indigenous rice varieties and millets declined. This led to the loss of distinct in-

indigenous crops from cultivation and also caused extinction. This review deals with the impacts the Green Revolution had on the production of indigenous crops, its effects on society, environment, nutrition intake, and per capita availability of foods, and also the methods that can be implemented to revive the indigenous crops back into cultivation and carry the knowledge to the future generation forward (Nelson, Ravichandran and Anthony, 2019) [1].

- The introduction of hybrid seeds in India has doubled the yield of foodgrains. The High Yielding Variety Seed Program (H.V.P.) has contributed to serious interregional disparities in agriculture. Surplus production of foodgrains is not the true measure of success of the Green Revolution; many areas in India remain unaffected by this program, and are still vulnerable to famines (Chakravarti, 2010) [2].
- The Indian empirical studies suggest a wide diffusion of modern varieties (MVs) among farmers, over time, irrespective of farm size and tenurial status. But the pace of diffusion of MVs of a given crop among farms, across the regions and over the years has certainly revealed a tendency to be interlinked with the nature and level of their (regions) development in physical and institutional infrastructure. (ii) Through prospects of increased demand for labour, the green revolution has undoubtedly exerted a favourable impact on the absolute income status of the landless labourer, notwithstanding the fact that the owners of land and capital have gained relatively more than the labourers in the increased production due to MVs. (iii) The impact of MVs on regional income differences has been one of increasing the gap mainly due to an interplay between differentials in levels of physical and infrastructural development of regions and product- location-specificity characteristics of MVs (Prahadachar, 1983) [3].
- The Green Revolution continues to be a touchstone in debates on food production. Accounts generally cite “high-yielding” dwarf wheat and rice spreading through Asia and particularly India, resulting in lives saved, agriculture modernised, and under-utilised workers moved off farms. This Commentary examines the forces that popularised this version of events and then reviews a significant new body of writing, comprising five major works by historians. The new work provides a fundamental rethinking of many key aspects of the revolution, including the motivations behind it, the merits of the agricultural science in India that it displaced, whether the new seeds actually led to increased food production, and how concepts of desirable plants changed (Stone, 2019) [4].

- This is a new history of irrigation and food production in twentieth-century India. It seeks to challenge the known story of Green Revolution, to question the role of plant breeding in the history of twentieth century agriculture and to de-centre the big dam from our picture of water and modernity. This thesis argues that there is no evidence of a breakthrough in Indian food production the 1960s and 1970s where a Green Revolution is typically placed; this was in fact a period of relatively slow growth in foodgrain production and yields within an era of high growth that had actually begun around 1950. Wheat, which was a small part of India’s food basket was an exception to this general trend of slow growth in the 1960s and 1970s. I argue that High Yielding Varieties of seeds had little to do with this leap in productivity; this was driven by a quick expansion in irrigation facilitated by private tubewells (Subramanian, 2015) [5].

Here’s how it came about and the role of HYV seeds

The Green Revolution emerged in the mid-20th century as a response to the pressing need to increase agricultural productivity to feed a rapidly growing global population. One of the key components of the Green Revolution was the development and widespread adoption of High-Yielding Variety (HYV) seeds.

High-Yielding Variety (HYV) seeds were a pivotal component of the Green Revolution, fundamentally transforming global agriculture in the mid-20th century. Here’s more about HYV seeds:

- **Characteristics:** HYV seeds were characterized by their ability to produce significantly higher yields compared to traditional varieties under optimal growing conditions. They were bred to possess traits such as shorter stature, disease resistance, pest resistance, and higher responsiveness to fertilizers and irrigation.
- **Crop Varieties:** HYV seeds were developed for various staple crops, including wheat, rice, maize (corn), sorghum, and millet. These crops were selected based on their importance in global food production and consumption.
- **Breeding Techniques:** Initially, HYV seeds were developed through conventional breeding techniques, which involved selecting and crossing plants with desirable traits over multiple generations. Later, advancements in biotechnology, such as genetic engineering and molecular breeding, contributed to the development of more sophisticated HYV varieties with targeted traits.
- **Global Adoption:** HYV seeds were widely adopted across different regions of the world, particularly in developing

countries facing food security challenges. Countries such as India, Mexico, the Philippines, and parts of Africa saw significant increases in agricultural productivity following the adoption of HYV seeds.

- **Impact on Yields:** The introduction of HYV seeds led to substantial increases in crop yields. For example, in India, the adoption of HYV wheat varieties, such as “Kalyan Sona” and “Lok 1,” resulted in yield increases of several hundred percent compared to traditional varieties.
- **Food Security:** The increased productivity associated with HYV seeds played a crucial role in improving food security by boosting the availability of staple crops. It helped alleviate hunger and malnutrition in many parts of the world by ensuring a more stable food supply.
- **Challenges and Concerns:** Despite their benefits, the widespread adoption of HYV seeds also raised various challenges and concerns. These included environmental issues such as soil degradation, water depletion, loss of biodiversity, and increased reliance on chemical inputs like fertilizers and pesticides. Additionally, the focus on a few high-yielding crop varieties led to reduced genetic diversity, which could potentially make agricultural systems more vulnerable to pests and diseases.

Overall, HYV seeds revolutionized agriculture by significantly increasing crop yields and contributing to global food security. However, their adoption also highlighted the importance of sustainable agricultural practices to mitigate potential negative environmental and social impacts.

Role of HYV seeds

- **Emergence of Concerns:** In the mid-20th century, particularly after World War II, there was a growing concern about the ability of agriculture to keep pace with the increasing global population. Traditional farming methods were often unable to produce enough food to meet the needs of a rapidly growing population.
- **Scientific Research:** Agricultural scientists and researchers began experimenting with different methods to boost agricultural productivity. They focused on developing crop varieties that could produce higher yields under optimal conditions.
- **Development of High-Yielding Varieties (HYVs):** Through selective breeding and later, genetic engineering techniques, scientists developed High-Yielding Varieties (HYVs) of staple crops such as wheat, rice, and maize. These varieties were characterized by traits such as shorter growing cycles, resistance to diseases and pests, and higher responsiveness to fertilizers.
- **Spread of HYV Seeds:** The HYV seeds were introduced to farmers as part of agricultural extension programs by governments, international organizations, and agricultural development agencies. These programs aimed to educate farmers about the benefits of using HYV seeds and provided them with access to these improved varieties.
- **Impact on Agriculture:** The adoption of HYV seeds led to a significant increase in agricultural productivity in many parts of the world. Farmers who switched to HYV seeds saw dramatic improvements in yields, which helped to alleviate food shortages and improve food security.
- **Challenges and Criticisms:** While the Green Revolution brought about substantial increases in agricultural production, it also faced criticisms. Concerns were raised about its environmental impacts, including the depletion of natural resources, soil degradation, and increased use of chemical fertilizers and pesticides. Additionally, the benefits of the Green Revolution were not evenly distributed, leading to socio-economic disparities among farmers.

Overall, the development and adoption of HYV seeds played a crucial role in the Green Revolution by significantly increasing agricultural productivity and helping to address food security challenges, albeit with some accompanying challenges and criticisms.

Achievements of green revolution

The Green Revolution brought about significant achievements in agricultural productivity, food security, and socio-economic development. Here are some of its key achievements:

- **Increased Agricultural Productivity:** The Green Revolution, driven by the introduction of High-Yielding Variety (HYV) seeds, marked a turning point in agricultural productivity. These seeds, developed through selective breeding and later genetic engineering, possessed traits that significantly boosted yields of staple crops like wheat, rice, and maize. Farmers witnessed substantial increases in output per unit of land, laying the foundation for enhanced food production worldwide.
- **Food Security:** Central to the Green Revolution’s impact was its contribution to global food security. By bolstering the availability of staple crops, particularly in regions with burgeoning populations, it alleviated the specter of hunger and malnutrition. Countries adopting Green Revolution technologies experienced reduced reliance on food imports, fortifying their ability to meet the dietary needs of their citizens and safeguarding against food crises.
- **Poverty Alleviation:** The Green Revolution served as a powerful engine for poverty alleviation, empowering smallholder farmers with increased incomes and economic opportunities. By enhancing agricultural productivity and farm profitability,

it enabled the farmers to break free from the shackles of poverty and improve their livelihoods. This economic upliftment extended beyond the farm gate, invigorating rural economies and fostering broader socio-economic development.

- **Rural Development:** At its core, the Green Revolution catalysed rural development by spurring investments in agricultural infrastructure and ancillary sectors. Governments and development agencies channelled resources into irrigation projects, rural roads, and market facilities, enhancing the agricultural ecosystem's resilience. Improved access to markets, technology, and finance empowered farmers to adopt modern farming practices, driving sustained growth in rural areas.
- **Technological Innovation:** The success of the Green Revolution ignited a wave of technological innovation in agriculture, propelling the sector into a new era of productivity and efficiency. Agricultural research institutions intensified efforts to develop superior crop varieties, innovative agronomic practices, and integrated pest management strategies. These advancements not only bolstered yields but also fostered resilience against emerging challenges such as climate change and pest outbreaks.
- **Global Spread of Agricultural Technologies:** The Green Revolution's triumphs resonated globally, sparking a wave of adoption in regions grappling with similar agricultural constraints. Through collaborative efforts between governments, international organizations, and research institutions, Green Revolution technologies were disseminated across continents. This inclusive diffusion extended the benefits of increased productivity and food security to marginalized communities, fostering greater equity in global food systems.
- **Environmental Awareness:** While hailed for its transformative impact, the Green Revolution also raised awareness about the environmental toll of intensive farming practices. Concerns over soil degradation, water scarcity, and biodiversity loss prompted a paradigm shift towards sustainable agriculture. The movement towards agroecology, organic farming, and conservation agriculture reflects a growing commitment to harmonize agricultural productivity with environmental preservation, ensuring the long-term sustainability of food production systems.

Each of these achievements underscores the multifaceted impact of the Green Revolution, shaping the trajectory of global agriculture and laying the groundwork for a more resilient, equitable, and sustainable food future.

Why did green revolution fade away?

The Green Revolution's decline can be attributed to a confluence of factors. Initially hailed for its transformative impact on

agricultural productivity, its success gradually gave way to diminishing returns. Continuous mono cropping and reliance on a few select crop varieties depleted soil fertility, while pests developed resistance to pesticides, leading to stagnant yields. Moreover, the intensive agricultural practices promoted by the Green Revolution raised significant environmental concerns, including soil erosion, water pollution, and loss of biodiversity. Socially, the benefits of the Green Revolution were unevenly distributed, exacerbating income inequality and rural poverty. Smallholder farmers, lacking access to resources, struggled to compete in an increasingly commercialized agricultural sector. Dependency on external inputs, such as chemical fertilizers and pesticides, created vulnerabilities to price fluctuations and supply chain disruptions, hindering the transition to more sustainable practices. Emerging challenges, such as climate change and water scarcity, further underscored the limitations of Green Revolution technologies in coping with evolving agricultural landscapes. Consequently, a paradigm shift towards more sustainable and resilient agricultural approaches, such as agro ecology and conservation agriculture, gained momentum, heralding a new era of agricultural development focused on ecological integrity, socio-economic equity, and long-term sustainability.

The Green Revolution's prominence began to wane due to several interconnected factors, including:

- **Diminishing Returns:** Over time, the initial surge in productivity gains associated with the adoption of High-Yielding Variety (HYV) seeds began to plateau. Continuous mono cropping and reliance on a few select crop varieties led to diminishing returns as soils became depleted of nutrients, pests developed resistance to pesticides, and water resources became increasingly stressed.
- **Environmental Concerns:** The intensive agricultural practices promoted by the Green Revolution raised significant environmental concerns. Soil erosion, water depletion, pollution from agrochemicals, loss of biodiversity, and deforestation became pressing issues as agricultural expansion intensified. Concerns over the long-term sustainability of these practices led to calls for more environmentally-friendly approaches to farming.
- **Social and Economic Disparities:** The benefits of the Green Revolution were not evenly distributed among farmers. Large landowners and wealthier farmers often reaped the majority of the gains, exacerbating income inequality and rural poverty. Smallholder farmers, who lacked access to resources such as credit, technology, and market networks, struggled to compete in the increasingly commercialized agricultural sector.

- **Dependency on Inputs:** The Green Revolution's reliance on chemical fertilizers, pesticides, and irrigation infrastructure created a cycle of dependency among farmers. Rising input costs, coupled with fluctuating commodity prices, squeezed profit margins for many farmers, particularly those operating on small-scale or marginal lands. This dependency made farming systems vulnerable to external shocks, such as price fluctuations or supply chain disruptions.
- **Emerging Challenges:** New challenges, such as climate change, pest and disease outbreaks, and water scarcity, began to emerge as threats to agricultural productivity. The Green Revolution technologies, which were developed under relatively stable climatic conditions, struggled to cope with the increasing unpredictability and extremes of weather patterns. Adaptation to these new challenges required innovative solutions beyond the scope of traditional Green Revolution approaches.
- **Shift in Agricultural Paradigms:** The shortcomings of the Green Revolution prompted a shift towards more sustainable and resilient agricultural paradigms. Agro ecology, organic farming, conservation agriculture, and precision agriculture emerged as alternative approaches that prioritize ecological integrity, biodiversity conservation, and community resilience. These approaches seek to optimize resource use, enhance soil health, and promote socio-economic equity while maintaining or improving agricultural productivity.
- **Globalization and Market Dynamics:** The globalization of agricultural markets and trade liberalization policies further challenged the viability of Green Revolution approaches. Increased competition from imported commodities, fluctuating commodity prices, and changing consumer preferences influenced farmers' decision-making and incentivized shifts towards more market-oriented and value-added agricultural practices.

While the Green Revolution's legacy continues to influence modern agriculture, its decline underscores the need for more holistic, context-specific, and sustainable approaches to address the complex challenges facing global food systems. The lessons learned from the Green Revolution era have paved the way for a renewed focus on agro ecological principles, resilience-building strategies, and inclusive development pathways aimed at achieving food security, environmental sustainability, and social equity in the 21st century.

How to make green evolution evergreen? Second green revolution

To ensure the continued relevance and sustainability of the Green Revolution, and to catalyze a "Second Green Revolution,"

it's imperative to adopt holistic and forward-thinking approaches to agricultural development. Building upon the successes and lessons learned from the first Green Revolution, the aim is to foster agricultural systems that are not only highly productive but also environmentally sustainable, socially equitable, and resilient to emerging challenges such as climate change and food insecurity. This requires a concerted effort from governments, international organizations, civil society, the private sector, and local communities to promote innovation, empower smallholder farmers, and transform food systems towards greater sustainability and inclusivity. Through strategic investments in research, technology, infrastructure, and capacity building, we can unlock the full potential of agriculture as a driver of sustainable development and ensure that the Green Revolution remains a beacon of hope for future generations.

To ensure that the Green Revolution remains relevant and sustainable in the long term, and perhaps spark a "Second Green Revolution," several key strategies can be implemented:

- **Promote Agro ecological Approaches:** Embrace agro ecological principles that prioritize biodiversity, soil health, and ecosystem resilience. Agro ecology integrates traditional knowledge with modern science to develop farming systems that are environmentally sustainable, socially equitable, and economically viable. Encouraging agro ecological practices can reduce reliance on external inputs, enhance ecosystem services, and build resilience to climate change.
- **Invest in Research and Innovation:** Allocate resources to agricultural research and innovation that address current and future challenges. Focus on developing crop varieties resilient to climate change, resistant to pests and diseases, and adaptable to diverse agro ecological conditions. Invest in precision agriculture technologies, digital farming tools, and data analytics to optimize resource use and improve productivity while minimizing environmental impact.
- **Empower Smallholder Farmers:** Support smallholder farmers with access to credit, markets, extension services, and technology. Strengthen farmer cooperatives and producer organizations to facilitate collective action, knowledge sharing, and market access. Promote inclusive policies that prioritize the needs and rights of smallholders, women farmers, and marginalized communities in agricultural development agendas.
- **Promote Sustainable Intensification:** Embrace sustainable intensification approaches that maximize productivity while minimizing environmental footprint. This includes practices such as conservation agriculture, integrated pest manage-

ment, and agroforestry, which enhance soil health, water efficiency, and biodiversity conservation. Encourage the adoption of climate-smart agricultural practices that improve resilience to climate variability and extreme weather events.

- **Foster Partnerships and Collaboration:** Forge partnerships and collaboration among governments, research institutions, civil society organizations, and the private sector to drive agricultural innovation and knowledge exchange. Foster multi-stakeholder platforms that facilitate dialogue, coordination, and collective action towards sustainable agriculture and food systems. Leverage international cooperation and South-South collaboration to share best practices, technologies, and experiences across regions.
- **Promote Sustainable Consumption and Production:** Encourage sustainable consumption and production patterns across the food value chain. Promote diversified diets, reduce food waste, and minimize post-harvest losses to ensure food security and nutrition for all. Support sustainable sourcing practices in food retail, catering, and hospitality sectors that prioritize ethical sourcing, environmental sustainability, and social responsibility.
- **Invest in Rural Infrastructure and Services:** Strengthen rural infrastructure and services, including transportation networks, market facilities, irrigation systems, and access to clean water and energy. Improve rural livelihoods through investments in education, healthcare, and social protection programs. Empower rural communities with access to information, education, and training opportunities to build their capacity and resilience.

By embracing these strategies, we can make the Green Revolution evergreen and pave the way for a sustainable and inclusive agricultural transformation that meets the needs of present and future generations.

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