Green Revolution in India and its significance in Economic Development .

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ABSTRACT

A detailed retrospective of the Green Revolution, its achievement and limits in terms of agricultural productivity improvement, and its broader impact at social, environmental, and economic levels is provided. Lessons learned and the strategic insights are reviewed as the world is preparing a “redux” version of the Green Revolution with more integrative environmental and social impact combined with agricultural and economic development. Core policy directions for Green Revolution 2.0 that enhance the spread and sustainable adoption of productivity enhancing technologies are specified.

The developing world witnessed an extraordinary period of food crop productivity growth over the past 50 y, despite increasing land scarcity and rising land values. Although populations had more than doubled, the production of cereal crops tripled during this period, with only a 30% increase in land area cultivated . Dire predictions of a Malthusian famine were belied, and much of the developing world was able to overcome its chronic food deficits. Sub-Saharan Africa continues to be the exception to Much of the success was caused by the combination of high rates of investment in crop research, infrastructure, and market development and appropriate policy support that took place during the first Green Revolution (GR). I distinguish the first GR period as 1966–1985 and the post-GR period as the next two decades. Large public investment in crop genetic improvement built on the scientific advances already made in the developed world for the major staple crops—wheat, rice, and maize—and adapted those advances to the conditions of developing countries ([2](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r2)).

The GR strategy for food crop productivity growth was explicitly based on the premise that, given appropriate institutional mechanisms, technology spillovers across political and agroclimatic boundaries could be captured. However, neither private firms nor national governments had sufficient incentive to invest in all of the research and development of such international public goods. Private firms operating through markets have limited interest in public goods, because they do not have the capacity to capture much of the benefit through proprietary claims; also, because of the global, nonrival nature of the research products, no single nation has the incentive to invest public resources in this type of research.

International public goods institutions were needed to fill this gap, and efforts to develop the necessary institutional capacity, particularly in plant breeding, were a central part of the GR strategy. Based on the early successes with wheat at the International Maize and Wheat Improvement Centre (CIMMYT) in Mexico and rice at the International Rice Research Institute (IRRI) in the Philippines, the Consultative Group on International Agricultural Research (CGIAR) was established specifically to generate technological spillovers for countries that underinvest in agricultural research, because they are unable to capture all of the benefits of those investments ([3](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r3)). After CGIAR-generated knowledge, invention, and products (such as breeding lines) were made publicly available, national public and private sectors responded with investments for technology adaptation, dissemination, and delivery.

Despite that success, in the post-GR period, investment in agriculture dropped off dramatically into the mid-2000s ([4](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r4)). However, the need for continued investments in agricultural innovation and productivity growth is as important today as it was in the early years of the GR. Low income countries and lagging regions of emerging economies continue to rely on agricultural productivity as an engine of growth and hunger reduction ([5](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r5)–[7](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r7)). However, sustaining productivity gains, enhancing smallholder competitiveness, and adapting to climate change are becoming increasingly urgent concerns across all production systems.

Since the mid-2000s and heightened after the 2008 food price spikes, there has been renewed interest in agricultural investment, and there are calls for the next GR, including those calls made by the former Secretary General of the United Nations Kofi Annan and Sir Gordon Conway . Simultaneously, there is recognition of the limitations of the first GR and the need for alternative solutions that correct for those limitations and unintended consequences ([5](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r5)). GR 2.0 must address these concerns both where the GR was successful and in low income countries and lagging regions, where agricultural productivity is still low. This paper reviews the evidence on the diffusion and impact of GR crop genetic improvements and the limitations and unintended environmental, social, and institutional consequences of the GR strategy for productivity growth. Then, I turn to the current period and the renewed interest and investment in agricultural development, and I give the technology and institutional priorities for Green revolution .

FIRST Green Revolution: DIFFUSION AND IMPACT OF CROP GENETIC IMPROVEMENTS

Positive impacts on poverty reduction and lower food prices were driven in large part by crop germplasm improvements in CGIAR centers that were then transferred to national agricultural programs for adaptation and dissemination. The productivity gains from crop germplasm improvement alone are estimated to have averaged 1.0% per annum for wheat (across all regions), 0.8% for rice, 0.7% for maize, and 0.5% and 0.6% for sorghum and millets, respectively ([9](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r9)). Adoption rates of modern varieties in developing countries increased rapidly, reaching a majority of cropland (63%) by 1998 ([9](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r9)–[15](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r15)).

However, global aggregates mask great geographic disparities. In Asian countries (including China), the percentage of area planted to modern varieties was 82% by 1998, whereas improved varieties covered only 27% of total area planted in Africa ([16](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r16)). This difference may be, in part, because of the later introduction of CGIAR research programs focused on Africa as well as the lag in breeding efforts for the orphan crops—crops that did not benefit from a backlog of research conducted before the GR period but had improvement that came during the GR and post-GR periods, such as cassava, sorghum, and millets—which are of greater relative importance to the African poor ([10](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r10)). For instance, the first CIMMYT maize program focused on Africa only began in the late 1980s. Although the International Institute for Tropical Agriculture research for cassava started in 1967, its impact was felt only since the 1980s ([10](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r10)). Although it lagged behind in the GR period, Africa has witnessed positive growth in the post-GR period. Adoption of improved varieties across sub-Saharan Africa reached 70% for wheat, 45% for maize, 26% for rice, 19% for cassava, and 15% for sorghum by 2005 ([17](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r17)).

Impact on Productivity and Food Prices.

The rapid increase in agricultural output resulting from the GR came from an impressive increase in yields per hectare. Between 1960 and 2000, yields for all developing countries rose 208% for wheat, 109% for rice, 157% for maize, 78% for potatoes, and 36% for cassava ([18](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r18)). Developing countries in southeast Asia and India were the first countries to show the impact of the GR varieties on rice yields, with China and other Asian regions experiencing stronger yield growth in the subsequent decades ([19](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r19)). Similar yield trends were observed for wheat and maize in Asia ([20](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r20)). Analysis of agricultural total factor productivity (TFP) finds similar trends to the partial productivity trends captured by yield per hectare [TFP is defined as the ratio of total output to total inputs in a production process ([20](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r20))] ([21](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r21)). For the period 1970–1989, change in global TFP for agriculture was 0.87%, which nearly doubled to 1.56% from 1990 to 2006 ([21](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r21)).

Crop genetic improvement focused mostly on producing high-yielding varieties (HYVs), but the decrease in time to maturity was also an important improvement for many crops, allowing for an increase in cropping intensity. The rapid spread of the rice–wheat system in the Indo-Gangetic plains (from Pakistan to Bangladesh) can be attributed to the shortening of the crop growing period ([22](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r22)). Other improved inputs, including fertilizer, irrigation, and to a certain extent, pesticides, were also critical components of the GR intervention. Asia had already invested significantly in irrigation infrastructure at the start of the GR and continued to do so throughout the GR and post-GR periods ([2](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r2)).

Widespread adoption of GR technologies led to a significant shift in the food supply function, contributing to a fall in real food prices ([23](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r23), [24](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r24)). Between 1960 and 1990, food supply in developing countries increased 12–13% ([25](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r25)). Estimates suggest that, without the CGIAR and national program crop germplasm improvement efforts, food production in developing countries would have been almost 20% lower (requiring another 20–25 million hectares of land under cultivation worldwide) ([26](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r26), [27](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r27)). World food and feed prices would have been 35–65% higher, and average caloric availability would have declined by 11–13% ([28](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r28)). Overall, these efforts benefited virtually all consumers in the world and the poor relatively more so, because they spend a greater share of their income on food ([29](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3411969/#r29)).

Green revolution in India.

The Green Revolution in India refers to a period when Indian [agriculture](https://en.wikipedia.org/wiki/Agriculture_in_India) was converted into an industrial system due to the adoption of modern methods and technology such as the use of [high yielding variety (HYV) seeds](https://en.wikipedia.org/wiki/High-yielding_variety), tractors, irrigation facilities, pesticides, and fertilizers. It was mainly found by [M.S. Swaminathan](https://en.wikipedia.org/wiki/M.S._Swaminathan). This was part of the larger [Green revolution](https://en.wikipedia.org/wiki/Green_revolution) endeavor initiated by [Norman Borlaug](https://en.wikipedia.org/wiki/Norman_Borlaug), which leveraged agricultural research and technology to increase agricultural productivity in the developing world.[[2]](https://en.wikipedia.org/wiki/Green_Revolution_in_India#cite_note-2)

The Green Revolution within [India](https://en.wikipedia.org/wiki/India) commenced in the early 1960s that led to an increase in food grain production, especially in [Punjab](https://en.wikipedia.org/wiki/Punjab,_India), [Haryana](https://en.wikipedia.org/wiki/Haryana), and [Uttar Pradesh](https://en.wikipedia.org/wiki/Uttar_Pradesh). Major milestones in this undertaking were the development of high-yielding varieties of [wheat](https://en.wikipedia.org/wiki/Wheat), and [rust](https://en.wikipedia.org/wiki/Rust_(fungus))resistant strains of wheat. However, agricultural scientists like [M.S.Swaminathan](https://en.wikipedia.org/wiki/M.S.Swaminathan" \o "M.S.Swaminathan) and social scientists like [Vandana Shiva](https://en.wikipedia.org/wiki/Vandana_Shiva" \o "Vandana Shiva) are of the opinion that it caused greater long term sociological and financial problems for the people of Punjab and India.

**Wheat**

The main development was higher-yielding varieties of [wheat](https://en.wikipedia.org/wiki/Wheat), for developing [rust](https://en.wikipedia.org/wiki/Rust_(fungus)) resistant strains of wheat The introduction of high-yielding varieties(HYV) of seeds and the increased quality of [fertilizers](https://en.wikipedia.org/wiki/Fertilizers) and [irrigation](https://en.wikipedia.org/wiki/Irrigation) technique led to the increase in production to make the country self-sufficient in food grains, thus improving [agriculture in India](https://en.wikipedia.org/wiki/Agriculture_in_India)[]](https://en.wikipedia.org/wiki/Green_Revolution_in_India#cite_note-7) The methods adopted included the use of [high-yielding varieties](https://en.wikipedia.org/wiki/High-yielding_varieties) (HYVs) of seeds with modern farming methods.

The production of wheat has produced the best results in fueling self-sufficiency of India. Along with high-yielding seeds and irrigation facilities, the enthusiasm of farmers mobilized the idea of agricultural revolution. Due to the rise in use of chemical pesticides and fertilizers, there was a negative effect on the [soil](https://en.wikipedia.org/wiki/Soil) and the land (e.g., [land degradation](https://en.wikipedia.org/wiki/Land_degradation)).

**Socioeconomic impacts**

The transition from traditional agriculture, in which inputs were generated on-farm, to Green Revolution agriculture, which required the purchase of inputs, led to the widespread establishment of rural credit institutions. Smaller farmers often went into [debt](https://en.wikipedia.org/wiki/Debt), which in many cases results in a loss of their farmland. The increased level of mechanization on larger farms made possible by the Green Revolution removed a large source of employment from the rural economy

The new economic difficulties of [smallholder](https://en.wikipedia.org/wiki/Smallholding) farmers and landless farm workers led to increased [rural-urban migration](https://en.wikipedia.org/wiki/Urbanization). The increase in food production led to a cheaper food for urban dwellers, and the increase in urban population increased the potential for industrialization

According to a 2018 paper, a 10 percent increase in the use of high-yielding crop varieties in developing countries in the period 1960–2000 led to increases in GDP per capita of approximately 15 percent.

**Greenhouse gas emissions**

According to a study published in 2013 in [PNAS](https://en.wikipedia.org/wiki/PNAS), in the absence of the crop germplasm improvement associated with the Green Revolution, [greenhouse gas](https://en.wikipedia.org/wiki/Greenhouse_gas) emissions would have been 5.2–7.4 Gt higher than observed in 1965–2004 High yield agriculture has dramatic effects on the amount of carbon cycling in the atmosphere. The way in which farms are grown, in tandem with the seasonal carbon cycling of various crops, could alter the impact carbon in the atmosphere has on global warming. Wheat, rice, and soybean crops account for a significant amount of the increase in carbon in the atmosphere over the last 50 years

**Dependence on non-renewable resources**

Most high intensity agricultural production is highly reliant on non-renewable resources. Agricultural machinery and transport, as well as the production of pesticides and nitrates all depend on fossil fuels Moreover, the essential mineral nutrient phosphorus is often a limiting factor in crop cultivation, while phosphorus mines are rapidly being depleted worldwide.[]](https://en.wikipedia.org/wiki/Green_Revolution#cite_note-72) The failure to depart from these non-sustainable agricultural production methods could potentially lead to a large scale collapse of the current system of intensive food production within this century.

**Health impact**

The consumption of the [pesticides](https://en.wikipedia.org/wiki/Pesticide) used to kill [pests](https://en.wikipedia.org/wiki/Pest_(organism)) by humans in some cases may be increasing the likelihood of cancer in some of the rural villages using them.[[73]](https://en.wikipedia.org/wiki/Green_Revolution#cite_note-Loyn-73) Poor farming practices including non-compliance to usage of masks and over-usage of the chemicals compound this situation In 1989, WHO and UNEP estimated that there were around 1 million human pesticide poisonings annually. Some 20,000 (mostly in developing countries) ended in death, as a result of poor labeling, loose safety standards etc.

**Pesticides and cancer**

Contradictory epidemiologic studies in humans have linked phenoxy acid herbicides or contaminants in them with [soft tissue sarcoma](https://en.wikipedia.org/wiki/Soft_tissue_sarcoma) (STS) and malignant [lymphoma](https://en.wikipedia.org/wiki/Lymphoma), organochlorine insecticides with STS, non-Hodgkin's lymphoma (NHL), [leukemia](https://en.wikipedia.org/wiki/Leukemia" \o "Leukemia), and, less consistently, with cancers of the [lung](https://en.wikipedia.org/wiki/Lung_cancer) and [breast](https://en.wikipedia.org/wiki/Breast_cancer), [organophosphorous](https://en.wikipedia.org/wiki/Organophosphorous" \o "Organophosphorous)compounds with NHL and leukemia, and triazine herbicides with [ovarian cancer](https://en.wikipedia.org/wiki/Ovarian_cancer).

**Punjab case**

The Indian state of [Punjab](https://en.wikipedia.org/wiki/Punjab_(India)) pioneered green revolution among the other states transforming India into a food-surplus country] The state is witnessing serious consequences of [intensive farming](https://en.wikipedia.org/wiki/Intensive_farming) using chemicals and pesticides. A comprehensive study conducted by [Post Graduate Institute of Medical Education and Research](https://en.wikipedia.org/wiki/Post_Graduate_Institute_of_Medical_Education_and_Research) ([PGIMER](https://en.wikipedia.org/wiki/PGIMER)) has underlined the direct relationship between indiscriminate use of these chemicals and increased incidence of cancer in this region.[[78]](https://en.wikipedia.org/wiki/Green_Revolution#cite_note-cancer-78) An increase in the number of cancer cases has been reported in several villages including Jhariwala, Koharwala, Puckka, Bhimawali, and Khara

Environmental activist [Vandana Shiva](https://en.wikipedia.org/wiki/Vandana_Shiva" \o "Vandana Shiva) has written extensively about the social, political and economic impacts of the Green Revolution in Punjab. She claims that the Green Revolution's reliance on heavy use of chemical inputs and monocultures has resulted in water scarcity, vulnerability to pests, and incidents of violent conflict and social marginalization

A [Greenpeace](https://en.wikipedia.org/wiki/Greenpeace) Research Laboratories investigation of 50 villages in [Muktsar](https://en.wikipedia.org/wiki/Muktsar" \o "Muktsar), [Bathinda](https://en.wikipedia.org/wiki/Bathinda" \o "Bathinda) and [Ludhiana districts](https://en.wikipedia.org/wiki/Ludhiana_district)revealed that twenty percent of the sampled wells had nitrate levels above WHO limits for drinking water. The 2009 study linked the nitrate pollution with high use of synthetic nitrogen [fertilizers](https://en.wikipedia.org/wiki/Fertilizer).

# Conclusion

In conclusion the green revolution saved over a billion of people all over the world from famine and provided more food sources .

Although it had some negative effects on the environment such as using high level of pestisides chemicals .