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From Yield to Nutrition: Unpacking the Impacts of the Green Revolution on Public Health

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ABSTRACT

India has experienced periodic famines and droughts that have necessitated food imports. In 1950, the nation was experiencing a shortage of food grains due to the rapidly expanding population, which was placing increasing strain on the agricultural sector. The Green Revolution has contributed to a greater sense of self-assurance in our ability to produce food grains and maintain a balance between population growth and agricultural output. The output of rice and wheat, two important crops, has increased significantly as a result of the Green Revolution, which is its most notable achievement. The first Green Revolution had both positive and negative impacts on society and the environment. Despite the enormous amount of agricultural output, there are concerns regarding the nation's level of food security. Emerging countries, such as India, have experienced gains in food production worldwide. Several notable negative repercussions of the Green Revolution emerged in the years that followed. Before the Green Revolution, its benefits and drawbacks were not the subject of any independent research. Following the Green Revolution, government activities caused the output of wheat and rice to quadruple, while local rice types and millets experienced a decline in productivity. Consequently, several local crops have perished and are no longer cultivated.

INTRODUCTION

A famine was anticipated in India between 1947 and 1960 because the country's food supply could not keep pace with the growing population (Nelson et al. 2019). Each person had access to only 417 g of food each day (Ghosh et al. 2002). Due to debt, many farmers have turned into laborers without access to land. The food chain has also been negatively impacted by the current political atmosphere. Crops for consumption and commercial use are extremely scarce. At the same time, agronomist Norman Borlaug contributed significantly to the worldwide Green Revolution. He provided farmers with new seeds that responded well to fertilizers, grew swiftly, and were stocky and resistant to disease. With the assistance of geneticist Dr. M. S. Swaminathan, India's green revolution got underway (Somvanshi et al. 2020). It began in the 1960s and helped the country produce more food. This study examines the features of agricultural policy, the consequences of the first stage of the Green Revolution, and the impact of the revolution on the production of local crops, society, the environment, and eating habits. Unquestionably, the Green Revolution contributed to a short-term decrease in hunger and malnutrition (Davis et al. 2019).

High crop productivity was achieved by the green revolution through adapted measures such as increasing the area under cultivation, double-cropping (planting two crops instead of one per year), adopting HYV seeds, significantly increasing the use of inorganic pesticides and fertilizers, improving irrigation facilities, improving farm implements and crop protection measures, and modifying farm equipment (Singh 2000, Brainerd & Menon 2014). Substantial expenditures have been made on crop research, infrastructure, market expansion, and appropriate government support (Pingali 2012). Selections for increased potential yield, broad environmental adaptation, rapid growth, high-quality grain, resilience to biotic stress, insects, and pests, and tolerance to abiotic stress, such as drought and flooding, were among them (Khush et al. 2001).

Cereal crop productivity quadrupled during the Green Revolution, with only 30% more farmed area. This was accomplished worldwide, with a few noteworthy outliers. Not insignificant impacts on reducing food costs and poverty were also noted. Studies have also shown that, in the event that the green revolution had not occurred, the availability of calories would have decreased by 11–13%. The results of studies on crop development were even more impressive. Additionally, it has prevented hundreds of hectares of land from being converted into agricultural land. (Pingali 2012). India became self-sufficient by importing crops, thanks to the green revolution (Brainerd & Menon 2014). Previously, India used a ship-to-mouth approach to import food items (Ramachandran & Kalaivani 2018). The benefits of India's overall food security are undeniable. Consequently, there is a plethora of comprehensive and helpful information on the benefits of the green revolution.

However, over time, a variety of unanticipated but detrimental consequences of the Green Revolution have surfaced. This study examines the negative impact of the Green Revolution on India's food sector. Research from the departments of social sector development, conventional agriculture, and other relevant fields shows the benefits of the Green Revolution, such as higher yields and lower rates of mortality and malnutrition (Somvanshi et al. 2020, Von der Goltz et al. 2020). However, research from the public health and environmental ministries indicates that using less pesticide is sufficient to lessen the adverse effects (Gerage et al. 2017). Numerous studies have been conducted to ascertain the entire spectrum of consequences associated with pesticides, insecticides, and other related compounds.

To inform policy, this study argues that while many interventions, such as the Green Revolution, have been successful in the short term, if ecological principles are not considered, they may have detrimental long-term repercussions. (Clasen et al. 2019). This is the case even though this topic has been the focus of much research. It would take a lot more effort, time, and other resources to recover from environmental injury than to recover from the destruction of the ecosystem.

Therefore, every new endeavor must be evaluated for sustainability and environmental friendliness. It is not wise to apply pesticides more extensively in an environment that is constantly deteriorating. Alternatively, other approaches that promote economic expansion, increased yields, and reduced environmental effects can be used. Eventually, it is necessary to break the vicious cycle of problems, solutions, and negative consequences. A second green revolution is the focus of various countries (Ameen & Raza 2017, Armanda et al. 2019). Techniques to support sustainable agriculture should be considered. Thus, before history is repeated, a warning must be sent. This study analyzes the dual impact of the Green Revolution on agricultural productivity and public health, focusing on food security, nutritional shifts, and the decline of traditional crops in India.

The main issue with native seeds was not their low yield, but rather their inherent inability to tolerate the chemical fertilizers that were utilized, even though high-yielding monohybrid crops were introduced as part of the Green Revolution. Conversely, new types have been developed to increase yields when combined with more intensive irrigation and chemical fertilizers. Following the Green Revolution, a significant amount of chemical fertilizers was utilized, and their usage of chemical fertilizers for agricultural production increased.

The secondary data for the study were collected from the Ministry of Agriculture and Farmers Welfare (MOA&FW), the Ministry of Consumer Affairs, the Department of Food & Public Distribution System, the Government of India (GOI), and other pertinent websites and organizations. Descriptive trend analysis was used in the data analysis process to clarify and explain how the green revolution has affected food production and food security issues in India.

GREEN REVOLUTION

Benefits and Drawbacks of the Green Revolution

The phrase "Green Revolution" refers to an increase in crop productivity in Asian nations. Although crop output has generally increased, intensive farming has led to the emergence of several environmental problems. However, we are forced to cultivate more food crops in areas with high population densities. Productivity must rise, but in ways that are socially, economically, and ecologically sustainable in nature. This is referred to as the Evergreen Revolution (Swaminathan 2000). Approximately 51% of India's land area is devoted to agriculture, compared to 12% in China and 20% in the USA.

Nevertheless, India has a larger cultivable area than that of China. From a situation of food shortages and imports to one of food security and exports, Indian agriculture has undergone a lengthy journey. India is currently lagging behind China in terms of rice and wheat production.

The production and productivity of Indian agriculture grew significantly with the adoption of numerous Green Revolution components, although it is still much lower than that of wealthy countries. An outstanding accomplishment of the Green Revolution has been the notable rise in the yield of key crops, such as rice, wheat, sugarcane, cotton, oilseed, jute, and mesta. It has been shown that between 1950–1951 and 2020–21, there was a notable growth in the output of oilseeds, cotton, jute, sugarcane (GOI 2021), as well as mesta. Between 1960 and 1961, sugarcane production increased by more than 3.5 times compared to cotton output (Table 1).

The Green Revolution has significantly impacted Indian agribusiness. With the assistance of Fertilizer Manufacturing Companies (PSUs) and Fertilizer Manufacturing Cooperatives, India has the option to attain food production self-sufficiency. Additionally, India ranks second in the world in terms of consumption and third in terms of production. The Department of Fertilizers, Ministry of Chemicals and Fertilizers, and Government of India comprise the Decision-Making Body (Dasgupta et al. 1977). Food output and chemical fertilizer usage are positively correlated in India (Table 2). In addition to fertilizers, insecticides are used to increase the yield. Approximately 80% of India's urea excrement demands are met by exports, while the nation's phosphate manure may be produced domestically by the fertilizer industry. At the same time, though, India is heavily dependent on imports for the raw materials needed to make its phosphate and potassium fertilizers.

Punjab and Haryana are the top pesticide users. India uses 76% more pesticides than the rest of the world (44% more). The most important crops for pesticide use in the country are cotton, wheat, and rice (Kumar et al. 2013). Haryana and Punjab are two states that use pesticides the most. Pesticides are mostly used in agriculture to safeguard food grains and crops, and very small amounts are utilized in public health campaigns. In addition, pesticides are used in various farming jobs and to maintain local cleanliness. Seventy-five percent of use is accounted for by farming purposes, with the remaining 25 percent coming from other applications (Banerji et al. 2003).

From only 200 tons produced in the country in 1952, over 50,000 tons were produced by 1979. It has been discovered that the increased usage of pesticides poses risks to human and environmental health (Anwar et al.1997). In agriculture, pesticides are often used to enhance production, guarantee stored harvests, and manage disease vectors. Although there are advantages to using pesticides, there are risks to the health of non-target persons, such as those who are exposed to these agrochemicals on the job or in their environment (Agrawal et al. 2010). These mixtures are known to be hazardous to many systems of the human body, leading to biochemical and haematological irritations. Field workers in northern India are commonly exposed to pesticides such as pyrethroids, carbamates, organochlorines, and organophosphorus. Farmers are particularly exposed to these pesticides during work through inhalation and skin absorption (Bharti et al. 2007).

Table 1: Commercial Crop Production Before and Following the Green Revolution.

Year	Sugarcane (Million tonnes)	Cotton (Million bales*)	Jute & Mesta (Millon bales*)	Oilseeds (Million tonnes)	Rice (Million tonnes)	Wheat (Million tonnes)
1950-51	57.05	3.04	3.31	5.16	20.58	6.46
1955-56	60.54	4.18	5.39	5.73	27.56	8.76
1960-61	110.00	5.60	5.26	6.98	34.58	11.00
1965-66	123.99	4.85	5.78	6.40	30.59	10.40
1970-71	126.37	4.76	6.19	9.63	42.22	23.83
1975-76	140.60	5.95	5.91	10.61	48.74	28.84
1980-81	154.25	7.01	8.16	9.37	53.63	36.31
1985-86	170.65	8.73	12.65	10.83	63.83	47.05
1990-91	241.05	9.84	9.23	18.61	74.29	55.14
1995-96	281.10	12.86	8.81	22.11	76.98	62.10
2000-01	295.96	9.52	10.56	18.44	84.98	69.68
2005-06	281.17	18.50	10.84	27.98	91.79	69.35
2010-11	342.38	33.00	10.62	32.48	95.98	86.87
2015-16	348.45	30.01	10.52	25.25	104.41	92.29
2020-21	399.25	35.38	9.56	36.10	122.27	109.52

Source: Directorate of Economics & Statistics, DA&FW * 4th Advance Estimates. Computed from GOI (2022, Agricultural Statistics at a Glance 2021) and www.pib.gov.in, last update 28-07-2022.

Table 2: Comparison between India's fertilizer consumption and food grain production.

Year	Food grain production (in million metric tons)	Fertilizer consumption in nutrients (in lakh metric tons)
1980-81	129.59	60.64
1990-91	176.4	125.46
2000-01	196.81	167.02
2002-03	174.77	160.94
2003-04	213.19	167.99
2004-05	198.36	183.98
2005-06	208.6	203.41
2006-07	217.28	216.51
2007-08	230.78	225.70
2008-09	234.47	249.09
2009-10	218.2	264.86
2010-11	244.78	281.22
2011-12	259.32	277.90
2012-13	257.1	255.36
2013-14	265.0	244.82
2014-15	252.0	255.76
2015-16	251.6	267.53
2016-17	275.1	259.49
2017-18	285.0	265.91
2018-19	285.2	272.88
2019-20	297.5	293.69
2020-21	308.6	325.36

Source: Agricultural Statistics at a Glance 2021 and Ministry of Agriculture & Farmers Welfare, Government of India (2022).

The Green Revolution's Effects

Pesticide impact: The use of pesticides has significantly increased, and India is now one of Asia's top pesticide manufacturers (Narayanan et al. 2016). Even though this has significantly increased economic growth (Gollin et al. 2018), a significant amount of pesticides are found to be unnecessary in both developed and developing countries. For instance, it has been shown that pesticide levels beyond set standards have been found in freshwater, posing an expensive danger (Choudhary et al. 2018). Despite the fact that India uses significantly fewer pesticides on average than many other countries, there is still a high level of pesticide residue in the country. This greatly contaminates water and damages land. Another major issue arising from an imbalance among pests is pest assault. One bug species overpopulates and targets specific crops as a result of predator and prey pests being out of balance due to the increased pesticide use. This results in an imbalance in crop yield. More potent pesticides or novel pesticide varieties are needed to tackle the pests that destroy these crops. This has also disrupted the food chain (Narayanan et al. 2016).

Impact on water consumption: With 91% of the water utilized for agriculture currently, India has the biggest demand for freshwater consumption in the world, according to Kayatz et al. (2019). In many parts of India, irrigated agriculture is generating water stress (Davis et al. 2018). Water-intensive crops were introduced during the Green Revolution in India. The bulk of these crops are cereals, which provide over50% of the dietary water footprint in India (Kayatz et al. 2019). Because their production cycle is shorter, these crops require a large amount of net water. The International Rice Research Institute states that the current rice production growth requires flooding with water. Groundwater table irrigation pumps and canal systems have been developed to deliver water to crops that require a lot of water, such as rice and sugarcane (Taylor et al. 2019). Owing to its importance as a place for the cultivation of wheat and rice, Punjab is among the most water-deprived areas in India (Alisjahbana et al. 2020). Punjab is predicted to face water scarcity in the coming years (Kumar et al. 2018).The green revolution aimed to increase food production to a point where it could feed everyone. Environmental effects were not considered. (Taylor et al. 2019). The previous budget allotment allocated 9,828 crore INR for irrigation and 3,080 crore INR for agriculture, which did not include irrigation costs. This trend has continued over the last three years (NABARD 2020). Overall, agriculture produces 380,239 crore INR, or 16.5% of GDP. Given that the quantity of water required for agriculture has grown compared to other inputs, more money has been spent on water irrigation.

Impacts on air pollution: Burning agricultural trash has become one of the main causes of air pollution. Instead of growing crops in accordance with the natural cycle, as has been done traditionally, farmers in Punjab, the center of the green revolution, are burning their land to prepare for the next cycle. The following crop cycle starts unusually early because the hybrid crops brought forth by the Green Revolution have such a short crop cycle. This exacerbates the high pollution levels caused by the burning of agricultural waste in some parts of Punjab (Davis et al. 2018). Numerous greenhouse gases, including carbon dioxide, methane, and nitrogen oxides, may be released by this type of cultivation (de Miranda et al. 2015).

Impacts on soil fertility: The Green Revolution, a time of notable agricultural breakthroughs, was a major factor in enhancing food security and raising agricultural output. Higher levels of food production have been achieved by improving crop yields through the application of mineral fertilizers and pesticides, as well as by introducing improvements in plant breeding. However, the Green Revolution did not come without costs to the health of the land. During this time, the overuse of fumigants negatively impacted the microbial communities in the soil, interfering with vital processes, including plant development, crop residue breakdown, and nutrient cycling. Moreover, fumigant spraying has a detrimental impact on agricultural output and soil health, endangering human and environmental health.

The crop cycle is repeated to boost crop yield and decrease crop failure, which results in the loss of soil nutrients. (Srivastava et al. 2020). Similarly, because intense cropping techniques prevent crop waste and organic matter from returning to the soil, they also result in a loss of soil organic matter (Singh and Benbi 2016). As soil quality decreases, farmers increase their fertilizer use to meet the needs of emerging seed types (Chhabra 2020). The quantity of heavy metals in the soil, such as arsenic (As), lead (Pb), and cadmium (Cd), increases with the use of fertilizers and pesticides. Herbicides and weed killers are also hazardous to the environment, and their use of these alkaline chemicals after the green revolution has raised the pH of the soil (Sharma & Singhvi 2017). A multitude of soil characteristics, including the flow of silt from upper to lower layers and the decrease in organic carbon content, are negatively impacted by monoculture or the cultivation of only wheat and rice (Singh & Benbi 2016). Beneficial pathogens in the soil, which are necessary to preserve soil fertility, were eliminated using toxic chemicals. Decreasing soil fertility results in lower yields. Protecting soil fertility was compromised by hazardous chemicals. In addition, the physicochemical properties of the soil are negatively affected by the use of tractors and mechanization, which, in turn, affects the biological activity of the soil. Soil recovers using traditional methods when exposed to any stressor (Srivastava et al. 2020). However, this is not the case with contemporary techniques. A Haryana study found that the area has salinity, waterlogging, soil erosion, a falling groundwater level, a rising groundwater table linked to brackish water, and alkaline soil. These factors will affect food security and productivity in the future (Singh 2000). For over 30 years, agricultural output rose, but rice yields stalled and subsequently decreased even more, reaching 1.13% in 1995–1996 (Jain 2018). Similarly, wheat productivity began to decline in the 1950s due to monoculture planting and a reduction in genetic potential (Handral et al. 2017). Moreover, there has been a stagnation in the yield of potatoes, cotton, and sugarcane (Singh 2008). Currently, agriculture has a significant ecological impact and is projected to develop unsustainably globally (Prasad 2016).

Long-Term Effects of Intensive Agriculture Practices on Soil Fertility

Intensive agricultural techniques have various troubling long-term implications for soil fertility. The natural symbiosis between N-fixing diazotrophs and P-solubilizing bacteria is disrupted by the excessive use of inorganic chemical fertilizers, which lowers soil health and nutrient-use efficiency in agroecosystems (Kashyapt et al. 2025). In addition, the limited and unequal distribution of mineral reserves, especially phosphorus (P), around the world drives up the cost of fertilizer, which means that more fertilizer needs to be applied to meet the needs of new seeds as soil quality declines due to ongoing intensive cropping systems (Table 3).

The use of modern chemical pesticides in India dates back to 1947–1948, when certain DDT formulations were introduced. In our country, over 100 pesticides are used to combat illnesses and pests that pose a financial threat. Approximately 3750 tons of specialist material were used as insecticides at the beginning of the First Five-Year Plan. Before the Second Five-Year Plan ended, it increased to 25,000 tons, and towards the end of the Fourth Five-Year Plan, it reached 45,000 tons (Sharma & Parisi 2017). Although the Green Revolution's reliance on dangerous pesticide compounds has contributed to the dramatic increase in the world's grain production, particularly in developing nations, the widespread use of pesticides and manures has led to problems with the environment and general prosperity (Bull 1982, Patra et al. 2025).

Small farmers have chosen these pesticides because they are practical, appropriately open, and have a broad range of bioactivity. Among the many chemical mixtures to which humans may be exposed, pesticides have a unique situation in that they are intentionally released into the environment

Table 3: Consumption of fertilizers from 1980-2021.

Year	Consumption			
	N	P	K	Total
1981-82	40.69	13.22	6.73	60.64
1985-86	56.61	20.05	8.08	84.74
1990-91	79.97	32.21	13.28	125.46
1995-96	98.23	28.98	11.56	138.77
2000-01	109.20	42.15	15.68	167.02
2005-06	127.23	52.04	24.14	203.41
2010-11	165.58	80.50	35.14	281.22
2015-16	173.72	69.79	24.02	267.53
2020-21	204.04	89.78	31.54	325.36

Source: Directorate of Economics & Statistics, DA&FW * 4th Advance Estimates.

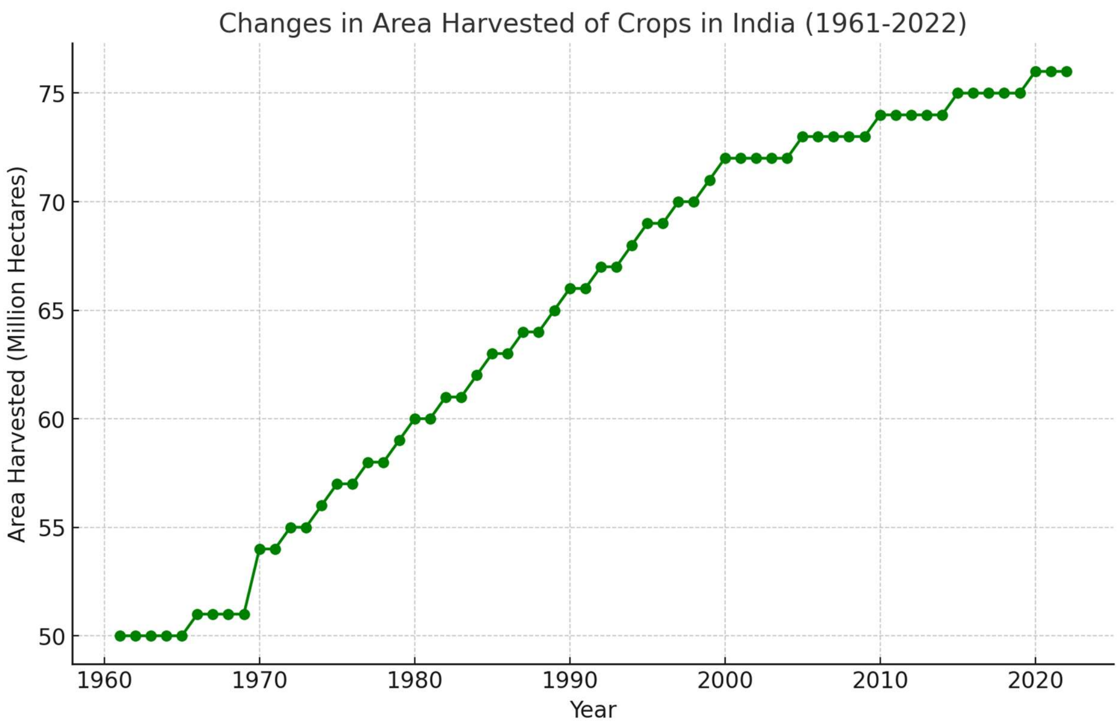
to destroy or injure specific types of life.

Impacts of Fertilizers on Human Health

After the Green Revolution, millets, which Indians had previously consumed in large quantities, became mostly fodder (Nelson et al. 2019). The Cambridge World History of Food (Kiple & Ornelas 2000) lists barley and millet among the grains that were part of the Asian diet. As mentioned earlier, the Green Revolution brought about significant changes in food production, which affected Indian eating patterns. The Food and Agriculture Organization (FAO) reported that rice production has increased, but millet production has decreased (Food and Agriculture Organization 2024). Rice began to take center stage in the national diet as a result. Despite making food more accessible, the Green Revolution led to a rise in calorie intake rather than a more diversified diet. Carbamate, pyrethroid, organochlorine, and organophosphate are the most commonly used pesticides. Adverse pesticide use has affected numerous aspects of human health, including the neurological, endocrine, immunological, and reproductive systems. The quantity of pesticides in the body may sometimes exceed the capacity of the detoxifying system due to long-term exposure to pesticides from various sources (Xavier et al. 2004). According to Sharma & Singhvi (2017), eating pesticide-containing food products is associated with exposure levels that are approximately 103–105 times higher than consuming tainted drinking water or air.

Crop Diversification After the 1990s

India's agricultural sector experienced more market-oriented policies with economic liberalization in the 1990s, resulting in a wider variety of crops. Farmers have started concentrating on more lucrative fruits, vegetables, horticultural crops, and export-oriented products such as sugarcane and cotton. This change increased the area planted with high-value crops while decreasing the area collected for traditional mainstays such as rice and wheat in some areas. Fig. 1 illustrates the changes in the area harvested for crops in India from 1961 to 2022. The x-axis on the graph represents the timeline in years spanning from 1960 to 2022, and the y-axis shows the total area harvested in million hectares. This shows the significant increases that occurred in the 1970s and the 1980s, corresponding to India's Green Revolution, which expanded agricultural practices and irrigation. The growth rate slowed after the 1990s, indicating the stabilization of agricultural land use. The graph reflects India's agricultural expansion over time, but also suggests that the scope for increasing the cultivated area has plateaued in recent decades, possibly due to land constraints or shifts toward productivity improvements. Initially, in 1961–1970, the dots are clustered



(data source: FAOSTAT, FAO 2024)

Fig. 1: Variations in the area of crops harvested between 1961 and 2022.

closer to 50–55 million hectares, indicating slow growth. During 1970–1990, the dots rose steadily, showing a sharp increase due to agricultural expansion and policy reforms, such as the Green Revolution. Stabilization occurred from 1990–2022 as the dots became nearly horizontal after 1990, remaining at approximately 75 million hectares, suggesting a plateau in the harvested area.

Immediate Effects of the Green Revolution

India's agricultural techniques were significantly impacted by the Green Revolution, which began in the late 1960s. The harvest areas for wheat and rice have increased owing to the introduction of high-yielding varieties (HYVs), chemical fertilizers, insecticides, and large irrigation systems. However, when farmers turned their attention to more lucrative crops, such as wheat and rice, coarse cereals, such as millets and sorghum, suffered sharp drops in acreage.

The main ecological and social effects of the Green Revolution are as follows: (1) loss of our nation's native landraces, (2) depletion of soil nutrients, rendering it unproductive, (3) overuse of pesticides, increasing residues in food and the environment, (4) farmers turning to unsustainable farming methods to increase yields, (5) rising rates of farmer suicide, (6) small farmers selling their lands to large commercial farmers due to inability to pay rising farming costs and debts, and (7) farmers abandoning farming in favor of other occupations due to the economic crisis and food inflation.

Impact of pesticides on farmers: Because they are unaware of the negative consequences of pesticides, most farmers who apply them do not use personal protective equipment (PPE), such as gloves and safety masks. When pesticides are sprayed on plants, they can immediately enter the body and cause blood nitrate levels, which render hemoglobin immobile. A lengthy period of exposure to organophosphates may potentially cause cancer. When it is present in trace levels, the substance may not be seen or tested, but years of consistent usage will create deposits in the body. Due to its capacity for bioaccumulate and severely harmful effects on humans, dichlorodiphenyltrichloroethane (DDT) was a common pesticide in India but is now illegal globally (Sharma & Singhvi 2017). Women comprise almost half of India's agricultural workforce, and as the majority of them are exposed to these poisons firsthand at a young age, they are more vulnerable to any detrimental effects, including those on their offspring. There is a strong correlation between the overall number of congenital disabilities and the concentration of agrochemicals in water. In developing countries such as India, agrochemicals have a larger negative impact on water (Brainerd & Menon 2014).

The excessive use of groundwater for irrigation has depleted the water table in many regions of the country, and the overuse of chemical fertilizers to achieve high yields alters the natural microflora and increases the soil's salinity and alkalinity, causing physical and chemical degradation.

Impacts of the green revolution on indigenous crops in India: Native crops are widely grown and well-known in their culture. The traditional meals and cereal-based products that were once staples of the average Indian diet have gradually vanished as a result of the Green Revolution's emphasis on monocropping. In addition to millets, wheat, barley, and maize, India's indigenous crops contain a range of rice varieties, including aromatic, colorful, and therapeutic varieties. Indigenous rice and millets are resistant to drought, salt, and floods. For instance, the Eastern Indian plants Dharical, Dular, and Tilak Kacheri may adapt to a variety of topographies, climates, and soil conditions (Richharia et al. 1990). Coarse grains include sorghum, pearl millet, barley, finger millet, maize, and small millets, including foxtail, proso, kodo, and baryard millet. Traditional rice cultivars are more nutrient-dense than hybrid rice varieties. (Bhat et al. 2015). They have more fiber and are a wonderful source of vitamins and minerals, including calcium, riboflavin, iron, niacin, and thiamine. Additionally, these cultivars have several health advantages, including a decreased glycemic and insulin response, which lowers the risk of type II diabetes, obesity, and cardiovascular illnesses (Umadevi et al. 2012). Kumbhar et al. (2015) reported that Vikram, a landrace from Maharashtra's Konkan area, and Tulshi tall, a landrace from the Western Ghat zone of Maharashtra, India, demonstrated a considerable degree of closeness in their different distinctions in allelic combinations from other contemporary varieties. This study argues that Indian landraces, local genotypes, and Basmati rice have a long and independent evolutionary history that distinguishes them from more modern varieties. Landraces are distinct and perfectly suited to the agro-climatic circumstances of their native farming regions. For instance, when grown in the somewhat warmer southern regions of West Bengal, India, Tulaipanji, a fragrant rice variety that was initially grown in the region's colder northern districts, lost its perfume (Deb et al. 2000). The scent and flavor of Kullu Valley's jatu rice are highly appreciated. Matali and Lal Dhan from Himachal Pradesh are used to cure fever and reduce hypertension, respectively. The Himalayan states of Uttar Pradesh and Himachal Pradesh are the origins of the well-known red rice variety Kafalya. It is used to treat difficulties resulting from abortion and leucorrhea (Ahuja et al. 2007). Assam black rice is used in Assam and northeastern India for its anti-cancer properties; its bran is used to prevent inflammation caused by asthma, allergies, and other ailments. In India, Rakthashali and Vellanavara are consumed for their health benefits, while Varla Chennellu and Chuvannachennellu are consumed by menopausal, pubescent, and pregnant women because they reduce issues related to hormonal imbalances. Chuvannakunjinelu is boiled with water and administered to people experiencing epileptic fits. The varieties of Kerala, such as Karinjan and Karimalakaran, are rich in fiber and known to lower the risk of diabetes, whereas Mundakan is consumed to increase stamina. (Nagarajan et al. 2018). Chhattisgarh and Jharkhand's Karhani is used as a tonic to treat epilepsy. Pregnant mothers ingest layacha to protect their unborn offspring from catching the sickness. Gastric disorders are treated with Gudna rice (Rahman et al. 2006). These are a few advantages of the few known types; many more remain unidentified and unstudied. Primary cereals are used to make foods like idli, aval, roti, dosai, dhokla, puttu, selroti, sez, khaman, adai, naan, kurdi and kulcha, sweets like jalebi, anarshe, and adirasam, snacks like vadai and murukku, and baby formulas. Deviet al. (2014) stated that millet is resistant to diseases, pests, and drought. Compared to other cereals, millets have a relatively short growth season and require minimal water for cultivation. Millets are used to make roti, dosai, kuzh (porridge), infant meals, ambali, wine, and health mixes, as well as treats like murukku. Millets contain polyphenols with anti-inflammatory and antioxidant properties (Chandrasekara et al. 2010). Because whole grains have a prebiotic effect, which increases the quantity of good bacteria in the stomach to aid in digestion, fermented millet products have been reported by Lei et al. (2006) to be a natural probiotic used to treat diarrhea in young children. Millets protect against heart disease, diabetes, obesity, and cancer. Although millets offer Several health However, their antinutrients hinder nutrient absorption. Millets provide several health benefits, but their anti-nutrients hinder nutrient absorption.

Crops	1961	2022	Difference
Wheat	12927k	30459k	Wheat, 17,532k
Soyabeans	11k	12147k	Soyabeans, 12,136k
Rice	34694k	46400k	Rice, 11,706k
Beans dry	6541k	15853k	Beans dry, 9,312k
Maize	4507k	9958k	Maize, 5,451k
Seed cotton	7719k	12372k	Seed cotton, 4653k
Sugarcane	2413k	5175k	Sugarcane, 2762k
Pigeon Peas	2433k	4900k	Pigeon Peas, 2467k
Chicks Peas	9276k	10740k	Chicks Peas, 1464k
Jute	917k	629k	Jute,-288k
Safflower seed	440k	79k	Safflower seed,-361k
Oilseeds nes	477k	109k	Oilseeds nes,-368k
Peas, dry	1177k	762k	Peas, dry,-415k
Sesame seed	2252k	1627k	Sesame seed,-625k
Pulses nes	3592k	2443k	Pulses nes,-1149k
Groundnuts, with shell	6889k	5705k	Groundnuts, with shell,-1184k
Linseed	1789k	197k	Linseed,-1592k
Barley	3205k	453k	Barley,-2752k
Millet	18657k	8489k	Millet,-10,168k
Sorghum	18249k	3801k	Sorghum,-14,448k

Fig. 2: Rate difference of crop at different times.

Extinction of Native Crop Varieties

India lost approximately one lakh of its native rice varieties as a result of the Green Revolution (Prasad 2016). Local types of rice, millets, lentils, and other crops have decreased since the start of the Green Revolution. Hybrid crops were therefore harvested more often because they grew faster (Taylor 2019). This is shown in Fig. 2. Wheat, soybeans, and rice are farmed at significantly higher rates. Additionally, the output of other millets, such as sorghum, barley, and groundnuts, has significantly decreased. (Singh 2019). Farmers' preferences also affect how they farm their crops. Natural oilseed crops, such as mustard, sesame, and others, along with certain pulses such as moong, gram, and tur, were farmed. Traditionally produced and consumed crops, such as millets, may thrive in dry and semi-arid regions because of their low water requirements. However, because no high-yielding millets were available, farmers shifted to planting only rice and wheat (Srivastava et al. 2020).

This study clearly shows that the required steps should be taken to preserve the country's native species and pass on knowledge to future generations by revitalizing the crops. All indigenous varieties' germplasms may be acquired and managed by the Indian government through the Indian National Genebank, located at the National Bureau of Plant Genetic Resources (NBPGR) in New Delhi. Farmer enthusiasm, stakeholder-initiated administrative actions, and vendor marketing techniques are the main drivers of the revival of indigenous crops. Furthermore, understanding the health advantages of native crops may help to save them from extinction and guarantee their availability in local markets and cooking techniques for future generations.

Food Security in India

Food security is defined as greater accessibility to sufficient food at all times for everyone (Krishna et al. 2015). Zero hunger, or the total eradication of hunger to provide food security for all people on the planet, is the second of the 17 Sustainable Development Goals (SDGs). Only by embracing sustainable agricultural methods will this be feasible. According to Kumar et al. (2018), agriculture is the only profession that employs 40% of the world's workforce. According to the United Nations Development Programme (UNDP), over 63% of the world's hungry people lived in Asia in 2017. Food insecurity is a major concern in the modern world, where food grain production is abundant but distribution is unequal, making it a problem that is not unique to any one nation. Feeding the growing population with wholesome food is quite difficult. A record-breaking state of food grain production is also caused by crop failure due to floods and droughts, declining water supplies, soil erosion, and climatic oddities. Another factor contributing to agricultural problems is farmers' ignorance of government regulations and what to do in the event of crop loss. Poor implementation of programs like PDS, poor management of food resources, very limited use of technology, lack of investment in research to find alternative sources of food, and lack of willpower in leaders are just a few of the issues that require the political class, bureaucracy, and civil society to properly address to integrate with the marginal and impoverished people of the land. Achieving food security is a significant achievement in a country where nearly one-third of the population lives in poverty and half of its children are malnourished.

The Green Revolution drastically changed India's food security position in the late 1960s. Over the past three to four decades, it has increased food grain output and stimulated economic growth. Despite the high population growth, which nearly doubled over that time, it reduced poverty and food insecurity by 50%. As a result, the nation can become food sufficient. With a current population of 1394 million and growing, India requires a significant amount of food grains. The current state of food security is good in terms of food availability, accessibility, and approachability compared to the pre-Green Revolution state. The Indian government implemented the Green Revolution approach to increase food grain production by expanding its area and yield. The mid-1960s saw the introduction of new seed-fertilizer technologies, which resulted in significant increases in wheat, rice, and subsequently, oilseed and cotton output levels. Food grain production has increased more than five times, from 50.82 million tonnes in 1950–51 to approximately 284.95 million tonnes in 2020–21.

Additionally, the proportion of cereals in the overall production of food grains grew from 83.5 percent in 1950-51 to 91.8 percent in 2020-21, while the proportion of pulses decreased from 16.54 percent to 8.19 percent in the same time frame. The combined percentage of rice and wheat in total cereals rose from 53.20 percent in 1950-51 to 76.51 percent in 2020-2021 (during which time the share of rice remained practically constant), whereas the percentage of coarse cereals fell from 30.3% to 15.3% during the same period. This indicates a shift in the consumption patterns of the poorer segments of society from nutri-cereals to wheat and to rice. Both Punjab and Haryana, the states with the highest agricultural output and food surplus, have benefited immensely from the Green Revolution.

Along with the Green Revolution, Haryana became a significant producer of food grains, especially rice and wheat, although the production of other coarse grains and pulses has decreased. Surplus output often increases agriculture's share of the state's gross domestic product and is traded to food-deficient states. Haryana ranked fifth in the 2009 India State Hunger Index. Haryana is behind Punjab, Kerala, Andhra Pradesh, and Assam (Kumar et al. 2018). India is self-sufficient in food grains, but if food security exists, why was the Food Security Law introduced in parliament? This suggests that the nation does not have sufficient food. Food security is significantly impacted by the unfair operation of the public distribution system (PDS). In actuality, thousands of individuals who live on the streets or as beggars in urban areas receive only one meal per day and endure malnutrition and starvation.

The Need for Food Policy

The Indian government is currently paying increased attention to the well-being of farmers. The establishment of several farmer welfare programs to enhance their financial circumstances and boost the agricultural industry. For the benefit of all Indian farmers, the government has launched new plans, programs, initiatives, and projects. Consequently, the government has launched new plans, programs, initiatives, and projects to help all Indian farmers. The central government took short-term steps to alleviate the food grain shortage: (a) extending the rationing system to include both cities and villages, (b) importing food grains to ease the situation, and (c) announcing subsidies for the distribution of imported food grains, which were more expensive than domestic produce. Since independence, governments have worked to ensure that food grains are available in sufficient quantities. Given the positive outcomes of their planning, planners became quite optimistic and thought that the food shortage issue had been resolved. The success attained over those years was attributed to favorable climatic circumstances and sufficient and timely rainfall; therefore, the scenario could not last for very long.

Droughts, floods, and cyclones revealed the food grain crisis during the Second Five-Year Plan. A major food crisis recurred in some sections of the country, particularly in 1958–59. The public distribution system was established to distribute imported food grains. Food grains were provided at a price below the market rate through a network of fair-pricing stores. To alleviate the scarcity of food grains, the central government implemented short-term measures to (a) expand the rationing system to include both cities and villages, (b) ease the situation by importing food grains, and (c) announce subsidies for the distribution of imported food grains, which were more costly than domestic produce. Heavy imports of food grains were implemented to stabilize the situation. For the next four years, India and the United States of America have an agreement in place to import 1 million tonnes of rice and 16 million tonnes of wheat. Therefore, during the ten-year era that included the 2nd and 3rd plan periods, food policy was predicated on imports, since around six million tons of food grains were imported annually. In 1966, the government implemented the integrated food strategy after realizing that deeper import strategies were not working and that food costs were still growing despite imports.

Numerous studies detailed the first Green Revolution's limits and effects on ecology and society. In light of these concerns, it has now been recognized that a second Green Revolution is necessary to ensure food and nutritional security for the majority of Indians while simultaneously boosting farm incomes and employment and emphasizing sustainable agriculture. Policy matters might include encouraging and offering a nutrient-dense, enhanced variety of seeds of prominent crops to diversify food production (Swaminathan 2020). Human population growth is accompanied by a decline in soil fertility and an increase in the usage of chemical pesticides and fertilizers, which are detrimental to both human health and the environment. The socioeconomic and environmental facets of agriculture growth nationwide shouldn't have any more detrimental effects. The next policy action should also focus on environmental and land deterioration.

The goal is to create genetically diverse millet cultivars that are resistant to both biotic and abiotic stressors. In the past, genetically engineered rice, wheat, and herbicides were introduced to obtain formal nutrition, which quickly resulted in environmental disaster. Deteriorating soil degradation and water depletion may soon lead to food shortages. Care should be taken while implementing new treatments to avoid interference with other systems or future problems. Any disturbance to the environment is predicted to have a cascading effect, meaning that if one link in the food chain is impacted, it will also affect other links. Agricultural pesticides are found in soil, surface water, and runoff, and are released into the environment by leaching, runoff, and air drift. This can contaminate water, soil, and other plants. Almost all habitats, including those of marine and terrestrial animals, have been shown to contain pesticide residues (Choudhary et al. 2018). Among these, biomagnification or bioamplification occurs when contaminated food is consumed, and bioconcentration occurs when the substance is absorbed through the gills or teguments. High concentrations of persistent organic pollutants have been discovered in seagrass meadows, coral reefs, and marine ecosystems (Dromard et al. 2018). It also affects the activities of insects and microbes. It contaminates animal products, including spinach, goats, and cattle, kills insects and plants, and poisons fish and birds. This can lead to bioaccumulation in humans, impairing their overall health and nutrition and decreasing food safety. Repeated application leads to biodiversity loss (Choudhary et al.2018). In addition to other symptoms, eating food tainted with pesticides can induce nausea, abdominal cramps, weakness and vomiting (Gerage et al. 2017). The decline of bumblebee colonies, a major pollinator group worldwide, is one illustration of the falling number of pollinators (Baron et al. 2017). The loss of honeybee colonies poses a major danger to human existence (Hagopian 2017). The quantity of residue left by these pesticides depends on the organism's environment and hierarchy. The usage of pesticides is expected to triple in the next years, making this a serious problem (Choudhary et al. 2018). Additionally, there is very little chance that the extinct native rice varieties will ever be found again. Other indigenous grains, such as millets, should not go extinct as a result of further advancements.

In summary, the consequences of the Green Revolution are still being felt today. The Green Revolution has had unanticipated yet negative repercussions on agricultural and human health, notwithstanding its contribution to food security. This necessitates testing and piloting new treatments before launching them, and the continuous evaluation of the benefits and drawbacks should guide the process.

The consequences of the Green Revolution have impacted an already fragile food chain. Since they might alter the narratives of growth and prosperity, possible disadvantages are rarely discussed. Long-term sustainability may be a concern for developments implemented due to necessity. Organic farming systems are essential for sustainable agricultural operations. Similarly, alternative farming practices such as intercropping and Zero Budget Natural Farming (ZBNF), which follow the core principles of promoting natural processes and eliminating external inputs, can be used (Khadse et al. 2018). The governments of Karnataka and Andhra Pradesh (AP), two southern Indian states, plan to convert 6 million farmers and 8 million hectares of land under the state initiative of Climate Resilient Zero Budget Natural Farming, owing to the positive outcomes of the ZBNF impact assessments in these states (Reddy et al. 2019, Koner & Laha 2020). Crop yields have reportedly increased by 40% for ragi and 9% for rice in AP. Groundnuts saw a 135% increase in net income compared to 25% for ragi. (Martin-Guay et al. 2018, Reddy et al. 2019).

Malnutrition, food insecurity, and associated issues must be addressed using a systematic approach. The Green Revolution, for instance, was initiated to mitigate the yield decline problem. There are presently plans for a second green revolution. There are presently plans for a second green revolution. Before putting such ideas into practice, environmental risk assessments and other studies are required. To secure a sustainable future, research should be conducted.

CONCLUSIONS

The Green Revolution undeniably transformed global agriculture, rescuing millions from famine and establishing food security in countries like India. By introducing high-yielding crop varieties, chemical fertilizers, and irrigation, it dramatically boosted cereal production, turning food-deficient nations into self-sufficient ones. However, these gains came at significant environmental and public health costs. Intensive farming practices degraded soil health, depleted groundwater, and increased pollution from agrochemicals, while the decline of indigenous crops reduced dietary diversity and nutritional security. Public health impacts were paradoxical: while calorie availability improved, malnutrition persisted due to imbalanced diets, and pesticide exposure led to severe health crises in farming communities. Socio-economic disparities have widened as wealthier farmers reap disproportionate benefits, leaving smallholders burdened with debt and marginalized regions neglected. Moving forward, a more sustainable agricultural model must integrate the lessons learned from the Green Revolution. Policies should promote agroecological practices, diversify cropping systems to include nutrient-rich traditional crops, and ensure equitable access to resources for all. By balancing productivity with environmental stewardship and nutritional security, future agricultural reforms can avoid the pitfalls of the past while sustainably feeding a growing population. The challenge lies not only in increasing yield but also in ensuring that food systems are resilient, equitable, and health-conscious.

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REFERENCES

Agrawal, A. and Sharma, B., 2010. Pesticides induce oxidative stress in mammalian systems. *International Journal of Biological & Medical Research*, 1(3), pp.90–104.

Ahuja, U., Ahuja, S.C., Chaudhary, N. and Thakrar, R., 2007. Red rice – past, present, and future. *Asian Agri-History*, 11(4), pp.291–304.

Alisjahbana, A.S., 2020. Asia-Pacific response to COVID-19 and climate emergency must build a resilient and sustainable future. United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP).

Ameen, A. and Raza, S., 2017. Green revolution: A review. *International Journal of Advanced Scientific Research*, 3(12), pp.129–137. [DOI]

Anwar, W.A., 1997. Biomarkers of human exposure to pesticides. *Environmental Health Perspectives*, 105(Suppl. 4), pp.801–806.

Armanda, D.T., Guinée, J.B. and Tukker, A., 2019. The second green revolution: Innovative urban agriculture's contribution to food security and sustainability – a review. *Global Food Security*, 22, pp.13–24. [DOI]

Banerji, R. and Dixit, B.S., 2003. Monitoring of pesticide residue in summer fruits and vegetables growing on the riverbed side. *Bulletin of Environmental Contamination and Toxicology*, 70(4), pp.783–788.

Baron, G.L., Jansen, V.A., Brown, M.J. and Raine, N.E., 2017. Pesticide reduces bumblebee colony initiation and increases probability of population extinction. *Nature Ecology & Evolution*, 1, pp.1308–1316. [DOI]

Bharti, M. and Taneja, A., 2007. Contamination of vegetables of different seasons with organophosphorus pesticides and related health risk assessment in Northern India. *Chemosphere*, 69(1), pp.63–68.

Bhat, F.M. and Riar, C.S., 2015. Health benefits of traditional rice varieties of temperate regions. *Medicinal and Aromatic Plants*, 4(3), p.198.

Brainerd, E. and Menon, N., 2014. Seasonal effects of water quality: The hidden costs of the Green Revolution to infant and child health in India. *Journal of Development Economics*, 107, pp.49–64. [DOI]

Bull, D., 1982. *A Growing Problem: Pesticides and the Third World Poor*. Oxfam, p.169.

Chandrasekara, A. and Shahidi, F., 2010. Content of insoluble bound phenolics in millets and their contribution to antioxidant capacity. *Journal of Agricultural and Food Chemistry*, 58, pp.6706–6714.

Chhabra, V., 2020. Studies on use of biofertilizers in agricultural production. *European Journal of Molecular and Clinical Medicine*, 7, pp.2335–2339.

Choudhary, S., Yamini, N.R., Yadav, S.K., Kamboj, M. and Sharma, A., 2018. A review: Pesticide residue – cause of many animal health problems. *Journal of Entomology and Zoology Studies*, 6, pp.330–333.

Clasen, B., Murussi, C. and Storck, T., 2019. Pesticide contamination in Southern Brazil. In: Gómez-Oliván, L.M. (ed.), *Pollution of Water Bodies in Latin America*. Springer, Paraná, pp.43–54. [DOI]

Dasgupta, B., 1977. India's Green Revolution. *Economic and Political Weekly*, 12(5), pp.241–260.

Davis, K.F., Chhatre, A., Rao, N.D., Singh, D., Ghosh-Jerath, S., Mridul, A., Poblete-Cazenave, M., Pradhan, N. and DeFries, R., 2019. Assessing the sustainability of post-Green Revolution cereals in India. *Proceedings of the National Academy of Sciences of the United States of America*, 116, pp.25034–25041. [DOI]

Davis, K.F., Chiarelli, D.D., Rulli, M.C., Chhatre, A., Richter, B., Singh, D. and DeFries, R., 2018. Alternative cereals can improve water use and nutrient supply in India. *Science Advances*, 4(10), eaao1108. [DOI]

De Miranda, M.S., Fonseca, M.L., Lima, A., de Moraes, T.F. and Rodrigues, F.A., 2015. Environmental impacts of rice cultivation. *American Journal of Plant Sciences*, 6, pp.2009–2018. [DOI]

Deb, D., 2000. *Folk Rice Varieties of West Bengal: Agronomic and Morphological Characteristics*. Research Foundation for Science, Technology and Ecology, New Delhi.

Devi, P.B., Vijayabharathi, R., Sathyabama, S., Malleshi, N.G. and Priyadarisini, V.B., 2014. Health benefits of finger millet (*Eleusine coracana* L.) polyphenols and dietary fibre: A review. *Journal of Food Science and Technology*, 51(6), pp.1021–1040.

Dromard, C.R., Bouchon-Navaro, Y., Cordonnier, S., Guéné, M., Harmelin-Vivien, M. and Bouchon, C., 2018. Different transfer pathways of an organochlorine pesticide across marine tropical food webs assessed with stable isotope analysis. *PLoS ONE*, 13(1), e0191335. [DOI]

Food and Agriculture Organisation (FAO), 2024. FAOSTAT: Food and Agricultural Data. Retrieved May 01, 2024, from http://www.fao.org/faostat/en/#data/QC

Gerage, J.M., Meira, A.P.G. and da Silva, M.V., 2017. Food and nutrition security: pesticide residues in food. *Nutrire*, *42*(1), p.3.

Ghosh, J., 2002. *Social Policy in Indian Development*. United Nations Research Institute for Social Development (UNRISD).

Gollin, D., Hansen, C.W. and Wingender, A., 2018. *Two Blades of Grass: The Impact of the Green Revolution*. National Bureau of Economic Research, Cambridge, MA. [DOI]

Hagopian, J., 2017. *Death and Extinction of the Bees*. Global Research.

Handral, A.R., Singh, A., Singh, D., Suresh, A. and Jha, G., 2017. Scenario of changing dynamics in production and productivity of major cereals in India. *Indian Journal of Agricultural Research*, 51(4), pp.210–222.

Jain, A., 2018. Analysis of growth and instability in area, production, yield and price of rice in India. *Journal of Social Change and Development*, 2, pp.46–66. Retrieved from http://www.okd.in/downloads/jr_18_july/article_4.pdf

Kashyap, P. and Jain, M., 2025. Organic farming: Emerging practices, effect on environment and nutrition. *Nature Environment and Pollution Technology*, 24(S1), pp.137–148. [DOI]

Kayatz, B., Harris, F., Hillier, J., Adhya, T., Dalin, C., Nayak, D., Green, R.F., Smith, P. and Dangour, A.D., 2019. "More crop per drop": Exploring India's cereal water use since 2005. *Science of the total environment*, *673*, pp.207-217. [DOI]

Khadse, A., Rosset, P.M., Morales, H. and Ferguson, B.G., 2018. Taking agroecology to scale: The Zero Budget Natural Farming peasant movement in Karnataka, India. *Journal of Peasant Studies*, 45(1), pp.192–219. [DOI]

Khush, G.S., 2001. Green revolution: The way forward. *Nature Reviews Genetics*, 2, pp.815–822. [DOI]

Kiple, K.F. and Ornelas, K.C. (eds.), 2000. *The Cambridge World History of Food*. Cambridge University Press, pp.1280. [DOI]

Koner, N. and Laha, A., 2020. Economics of zero budget natural farming in Purulia District of West Bengal: Is it economically viable? *Studies in Agricultural Economics*, 122, pp.22–28. [DOI]

Krishna, N., Kundapur, R., Kiran, N.U. and Badiger, S., 2015. Food security and nutrition consumption among households in the semi-urban field practice area of K.S. Hegde Medical Academy, Mangalore: A pilot study. *Nitte University Journal of Health Sciences*, 5(2), pp.31–37.

Kumar, N., Anand, S. and Singh, J., 2018. Understanding the status of food security: A case study of Haryana. *The Horizon: A Journal of Social Sciences*, 1(9), pp.1–18.

Kumar, R., Vaid, U. and Mittal, S., 2018. Water crisis: Issues and challenges in Punjab. *Water Resources Management*, 78, pp.93–103. [DOI]

Kumar, S., Sharma, A.K., Rawat, S.S., Jain, D.K. and Ghosh, S., 2013. Use of pesticides in agriculture and livestock animals and their impact on the environment of India. *Asian Journal of Environmental Science*, 8(1), pp.51–57.

Kumbhar, S.D., Kulwal, P.L., Patil, J.V., Sarawate, C.D., Gaikwad, A.P. and Jadhav, A.S., 2015. Genetic diversity and population structure in landraces and improved rice varieties from India. *Rice Science*, 22(3), pp.99–107.

Lei, V., Friis, H. and Michaelsen, K.F., 2006. Spontaneously fermented millet product as a natural probiotic treatment for diarrhoea in young children: An intervention study in northern Ghana. *International Journal of Food Microbiology*, 110, pp.246–253.

Martin-Guay, M.-O., Paquette, A., Dupras, J. and Rivest, D., 2018. The new green revolution: Sustainable intensification of agriculture by intercropping. *Science of the Total Environment*, 615, pp.767–772. [DOI]

Nagarajan, S., 2018. Indigenous rice varieties make a comeback. *The Hindu*, India. Retrieved from http://www.thehindu.com/life-and-style/food/thanals-save-our-rice-is-reviving-indigenous-rice-varieties/article22420554.ece

Narayanan, J., Sanjeevi, V., Rohini, U., Trueman, P. and Viswanathan, V., 2016. Postprandial glycaemic response of foxtail millet dosa in comparison to a rice dosa in patients with type 2 diabetes. *Indian Journal of Medical Research*, 144(5), pp.712–718.

National Bank for Agriculture and Rural Development (NABARD), 2021. *Annual Report 2020–21*. Mumbai: NABARD. Available at: https://www.nabard.org/nabard-annual-report-2020-21.aspx (Accessed: 24 October 2025).

Nelson, A.R.L.E., Ravichandran, K. and Antony, U., 2019. The impact of the Green Revolution on indigenous crops of India. *Journal of Ethnic Foods*, 6(8), pp.1–9.

Patra, P., Jaswal, A. and Fatima, I., 2025. Enhancing food security through sustainable agriculture: investigating the allelopathic effects of sorghum on weed management in field pea (*Pisum sativum* var. *arvense*). *Nature Environment & Pollution Technology*, 24(1), pp.120–128. [DOI]

Pingali, P.L., 2012. Green revolution: impacts, limits, and the path ahead. *Proceedings of the National Academy of Sciences of the United States of America*, 109(31), pp.12302–12308.

Prasad, S.C., 2016. Innovating at the margins: the System of Rice Intensification in India and transformative social innovation. *Ecology and Society*, 21(4), p.7.

Rahman, S., Sharma, M.P. and Sahai, S., 2006. Nutritional and medicinal values of some indigenous rice varieties. *Indian Journal of Traditional Knowledge*, 5(4), pp.454–458.

Ramachandran, P. and Kalaivani, K., 2018. Nutrition transition in India: challenges in achieving global targets. *Proceedings of the National Academy of Sciences of the United States of America*, 84(9), pp.821–833.

Reddy, B., Reddy, V. and Reddy, M.S., 2019. Potential and constraints of Zero Budgeted Natural Farming (ZBNF): a study of Andhra Pradesh. *Indian Journal of Agricultural Economics*, 74(3), pp.321–332. Available at: http://isaeindia.org/wp-content/uploads/2020/11/03-Article-M-Srinivasa-Reddy.pdf

Richharia, R.H. and Govindasamy, S., 1990. *Rices of India*. Karjat: Academy of Development Science, pp.1–350.

Sharma, N. and Singhvi, R., 2017. Effects of chemical fertilizers and pesticides on human health and environment: a review. *International Journal of Agriculture, Environment and Biotechnology*, 10(6), pp.675–680.

Sharma, R.K. and Parisi, S., 2017. *Toxins and Contaminants in Indian Food Products*. Springer International Publishing, pp.13–24.

Singh, I., 2019. Changes of agriculture production in India after the Green Revolution. *Journal of Gujarat Research Society*, 21(3), pp.2290–2294. Available at: http://gujaratresearchsociety.in/index.php/JGRS/article/view/2967

Singh, M.V., 2008. Micronutrient deficiencies in crops and soils in India, in: Alloway, B.J. (ed.) *Micronutrient Deficiencies in Global Crop Production*. Springer, pp.93–125.

Singh, R., 2000. Environmental consequences of agricultural development: a case study from the Green Revolution state of Haryana, India. *Agriculture, Ecosystems & Environment*, 82(1–2), pp.97–103.

Singh, S. and Benbi, D.K., 2016. Punjab-soil health and green revolution: a quantitative analysis of major soil parameters. *Journal of Crop Improvement*, 30(3), pp.323–340.

Somvanshi, P.S., Pandiaraj, T. and Singh, R.P., 2020. An unexplored story of the successful Green Revolution of India and steps towards the evergreen revolution. *Journal of Pharmacognosy and Phytochemistry*, 9(1), pp.1270–1273.

Srivastava, P., Balhara, M. and Giri, B., 2020. Soil health in India: Past history and future perspective. In: Giri, B. and Varma, A. (eds.) *Soil Health*. Springer, New Delhi, pp.1–19.

Swaminathan, M.S., 2000. An evergreen revolution. *Biologist*, 47(2), pp.85–89.

Swaminathan, M.S., 2020. *Baseline Survey Report: Strengthening Livelihoods and Enhancing Food and Nutrition Security of Small and Marginal Farmers in Koraput District of Odisha Through a Farming System Model*. M.S. Swaminathan Research Foundation, Chennai, pp.1–120.

Taylor, M., 2019. Hybrid realities: making a new Green Revolution for rice in South India. *Journal of Peasant Studies*, 47(3), pp.483–502.

Umadevi, M., Pushpa, R., Sampathkumar, K.P. and Bhowmik, D., 2012. Rice: A traditional medicinal plant. *Indian Journal of Pharmacognosy and Phytochemistry*, 1(1), pp.6–12.

Vaz, M., Yusuf, S., Bharathi, A., Kurpad, A. and Swaminathan, S., 2005. The nutrition transition in India. *South African Journal of Clinical Nutrition*, 18(3), pp.198–201.

Von der Goltz, J., Dar, A., Fishman, R., Mueller, N.D., Barnwal, P. and McCord, G.C., 2020. Health impacts of the Green Revolution: evidence from 600,000 births across the developing world. *Journal of Health Economics*, 74, p.102373.

Xavier, R., Rekha, K. and Bairy, K., 2004. Health perspective of pesticide exposure and dietary management. *Malaysian Journal of Nutrition*, 10(1), pp.39–51.