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Review

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

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ABSTRACT

India experienced periodic famines and droughts that made it necessary to import food. In 1950, the nation was experiencing a shortage of food grains due to the fast-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 increase 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 accomplishment. The first Green Revolution had an impact on society and the environment, both positively and negatively. Despite the enormous amount of agricultural output, there are some concerns over the nation's level of food security. There have been gains in food production worldwide in emerging countries such as India. Several notable negative repercussions of the green revolution surfaced in the years that followed prior to the green revolution, the 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 saw a decline in productivity. As a result, several local crops perished and were no longer cultivated.

INTRODUCTION

A famine was anticipated in India between 1947 and 1960 because the country's food supply could not keep up with the growing population (Nelson et al. 2019). Each person only had access to 417 grams of food each day (Ghosh et al. 2002). Due to debt, many farmers had turned into labours without access to land. The food chain was negatively impacted by the current political atmosphere as well. Crops for consumption and commercial use were both extremely scarce. At the same time, agronomist Norman Borlaug made a significant contribution to the world-wide green revolution. He provided farmers with new seeds that took 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 started in the 1960s and helped the country produce more food. This study looks at 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 like: increasing the area under cultivation; double-cropping, which is planting two crops instead of single year; adopting HYV seeds; significantly increasing the use of inorganic pesticides and fertilizers; improving irrigation facilities; and improving farm implements and crop protection measures and modifications in farm equipment (Singh 2000; Brainerd and Menon 2014). Substantial expenditures were made in crop research, infrastructure, market expansion, and appropriate governmental 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 drought and flooding, were among them (Khush et al. 2001).

Cereal crop productivity quadrupled with the green revolution on just 30% more farmed area. All around the world, this was accomplished, with a few noteworthy outliers. Not insignificant impacts on reducing food costs and reducing poverty were also noted. Studies also showed that, in the event that the green revolution had not occurred, the availability of calories would have decreased by 11–13%. Results from the studies on crop development were even more impressive. Additionally, it stopped hundreds of hectares of land from being turned into agricultural land. (Pingali et al. 2012). India was able to become self-sufficient by importing crops thanks to the green revolution (Brainerd and Menon, 2014). In the past, India used the ship-to-mouth approach to import food items (Ramachandran and Kalaivani 2018). Benefits to India's overall food security are undeniable. Consequently, there is a plethora of comprehensive and helpful information about the benefits of the green revolution.

But over time, a variety of unanticipated but detrimental consequences of the green revolution surfaced. This essay looks at how the green revolution has hurt 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 malnourishment. (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 enough to lessen the adverse effects. (Gerage et al. 2017). Numerous studies are being conducted to ascertain the entire spectrum of consequences connected to pesticides, insecticides, and other related compounds.

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

As such, every new endeavor must be evaluated for sustainability and environmental friendliness. It is not wise to keep applying pesticides more extensively in an environment that is constantly deteriorating. Alternatively, other approaches that promote economic expansion, increased yields, and less environmental effect can be used. Eventually, it is necessary to break the vicious cycle of problem, solution, and negative consequences. A second green revolution, for example, is the focus of various countries (Ameen and Raza 2017; Armanda et al. 2019). Techniques to support sustainable agriculture could be taken into consideration in its place. Thus, before history is repeated, a warning has to be sent. The objective of study is to analyze the dual impacts 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 that they were low-yielding, but rather that they were inherently unable 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 were developed to increase yields when combined with more intensive irrigation and chemical fertilizers. Following the Green Revolution, a significant amount of chemical fertilizers were utilized, and the usage of chemical fertilizers for agricultural production increased.

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

2. GREEN REVOLUTION

2.1. The benefits and drawbacks of the Green Revolution:

The phrase "Green Revolution" refers to increases in crop productivity in Asian nations. Crop output has generally grown, although intensive farming has led to the emergence of several environmental problems. We are forced to cultivate more food crops in areas with high population densities, nevertheless. Productivity must rise, but in ways that are socially, economically, and ecologically sustainable. The Evergreen Revolution is the term for this (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 China. From a situation of food shortages and imports to one of food security and exports, Indian agriculture has gone through 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 below 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.

Table1: Commercial Crop Production Prior to 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.

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 more than 3.5 times in comparison to cotton output. (Table 1).

Indian agribusiness has been significantly impacted by the Green Revolution. With the assistance of Fertilizer Manufacturing Companies (PSUs) and Fertilizer Manufacturing Cooperatives, India has the option to attain food production self-sufficiency. Additionally, India's position in the world is second 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 have been proven to positively correlate in India (Table 2). In addition to fertilizers, insecticides are used to increase yield. About 80% of India's urea excrement demands are met by exports, while the nation's phosphate manures 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.

The states of Punjab and Haryana are regarded as the top users of pesticides. India uses 76% more pesticides than the rest of the world (44%). The country's most important crops for pesticide use are cotton, wheat and rice (Kumar et al. 2013). Haryana and Punjab are two of the states that use pesticides the most. Pesticides are mostly used in

agriculture to safeguard food grains and crops; very little amounts are also utilized in public health campaigns. In addition, pesticides are used in various farming jobs and for maintaining 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).

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

Year	Food grain production (in million metric tons)	Fertilizers 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.

From only 200 tons produced in the country in 1952, over 50,000 tons were produced continuously by 1979. It has been discovered that the increased usage of pesticides poses risks to human and environmental health (Anwar et al.1997). In serious 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 non-target persons' health, such as those who are exposed to these agrochemicals on the job or in their environment (Agrawal et al. 2010). These mixes are known to be hazardous to the many systems of the human body, leading to biochemical and haematological irritations. It is rather common for field workers in northern India to be 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).

2.2.The Green Revolution's effects

2.2.1. Pesticide Impact:

The use of pesticides has significantly increased, and India is now one of Asia's top manufacturers of pesticides (Narayanan et al. 2016). Even while 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, presenting an expensive danger (Choudhary et al. 2018). Despite the fact that India uses significantly less pesticides on average than many other countries, there is still a high level of pesticide residue in the country. This greatly contaminates the water and damages the land. Another major issue that arises from an imbalance among the pests is pest assaults. One bug species overpopulates and targets specific crops as a result of predator and prey pests being out of balance due to increased pesticide use. The resulting imbalance in crop yield is caused by this. More potent pesticides or novel pesticide varieties would be needed to tackle the pests that are destroying these crops. This has also caused a disruption in the food chain (Narayanan et al. 2016).

2.2.2. 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 now generating water stress (Davis et al. 2018). Water-intensive crops were introduced during the Green Revolution. 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 also require a large amount of net water. The International Rice Research Institute states that present rice production growth requires flooding with water. Groundwater table irrigation pumps and canal systems were developed to deliver water to crops that require a lot of water, such rice and sugarcane (Taylor et al. 2019). Due to its importance as a place for the cultivation of wheat and rice, Punjab is among the most water-depleted areas of India (Alisjahbana et al. 2020). Punjab is predicted to face a water scarcity in the next years (Kumar et al. 2018).Soil toxicity and depletion of water resources led to an increase in subsurface water contamination.Raising food production to a point where it could feed everyone was the only objective of the green revolution. The effects on the environment 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. This tendency has continued over the last three years (NABARD, 2020). 380,239 crore INR, or 16.5% of GDP, is produced by agriculture overall (Economics, 2020; India, 2020). Given that the quantity of water required for agriculture has grown in comparison to other inputs, this means that more money has been spent on water irrigation.

2.2.3.Impacts on Air Pollution

Burning agricultural trash has grown to be one of the main causes of air pollution these days. 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 since the hybrid crops brought forth by the green revolution have such a short crop cycle. This exacerbates the high pollution levels brought on by burning agricultural waste in some parts of Punjab (Davis et al. 2018).

Numerous greenhouse gases, including carbon dioxide, methane, nitrogen oxides and others, may be released by this type of cultivation (de Miranda et al. 2015).

2.2.4.Impacts on Soil fertility

A major factor in enhancing food security and raising agricultural output was the Green Revolution, a time of notable agricultural breakthroughs. Higher levels of food production were achieved by improving crop yields through the application of mineral fertilizers and pesticides, as well as by introducing improvements in plant breeding. The Green Revolution did not, however, come without costs for the health of the land. During this time, the overuse of fumigants had a negative impact on 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 was repeated in an attempt to boost crop yield and decrease crop failure, which resulted in the loss of soil nutrients. (Srivastava et al. 2020). Similar to this, because intense cropping techniques keep crop wastes 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 decreased, farmers increased 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), rose with the use of fertilizers and pesticides. Herbicides and weed killers are hazardous for the ecology as well.The usage of these alkaline chemicals after the green revolution raised the pH of the soil (Sharma and 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 just wheat and rice (Singh and Benbi 2016). Beneficial pathogens in the soil, which are necessary to preserve soil fertility, were eliminated by toxic chemicals. The decreasing fertility of the soil results in a lower yield. protecting soil fertility, were removed by hazardous chemicals. In addition, the physicochemical properties of the soil were negatively impacted by the use of tractors and mechanization, which in turn affected the biological activity of the soil.Soil recovers by traditional methods when exposed to any kind of stressor (Srivastava et al. 2020). This isn't the case with these contemporary techniques, though. A Haryana research found that the area has salinity, waterlogging, soil erosion, a falling groundwater level, a rising groundwater table linked to brackish water, and an alkaline soil. These factors would affect food security and productivity in the future (Singh, 2000). For over thirty years, agricultural output rose, but rice yields stalled and subsequently decreased even more, reaching 1.13% in 1995–1996 (Jain, 2018). Similar to this, wheat productivity started to fall in the 1950s as a result of monoculture planting and a reduction in genetic potential (Handral et al. 2017). Moreover, there was a stagnation in the yield of potatoes, cotton, and sugarcane (Singh, 2008). Currently having a significant ecological impact, agriculture is projected to develop unsustainable globally (Prasad, 2016).

2.2.5. Long-Term Effects of Intensive Agriculture Practices on Soil Fertility

Intensive agricultural techniques have a variety of troubling long-term implications on soil fertility. The natural symbiosis between N-fixing diazotrophs and P-solubilizing bacteria has been shown to be disrupted by excessive use of inorganic chemical fertilizers, which lowers soil health and nutrient usage efficiency in agro ecosystems (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).

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.

The use of modern chemical pesticides in India dates back to 1947–1948, when certain DDT formulations were brought in. In our country, over 100 pesticides are now used to combat illnesses and pests that pose a financial threat. Around 3750 tons of specialist material were used as insecticides at the beginning of the First Five Year Plan. Before the IInd Five Year Plan ended, it increased to 25,000 tons, and towards the end of the IVth Five year plan, it reached 45,000 tons (Sharma and Parisi 2017). Even though the Green Revolution's reliance on dangerous pesticide compounds has contributed to the world's grain production rising dramatically, 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 so far chosen these pesticides because they are practical, appropriately open, and have a broad range of bioactivity. Among the many chemical mixtures to which man may be exposed, pesticides have a unique situation in that they are intentionally released into the environment with the intent to destroy or injure specific types of life.

2.2.6.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 and Ornelas, 2000) lists barley and millets among the grains that were part of the Asian diet. As mentioned before, 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 increased but millets decreased (Food and Agricultural 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. The classes of carbamate, pyrethroid, organochlorine, and organophosphate comprise the vast majority of pesticides used. Numerous aspects of human health, including the neurological, endocrine, immunological, and reproductive systems, have been impacted by adverse pesticide usage. The quantity of pesticides in the body might sometimes exceed the capacity of the detoxifying system due to long-term exposure to pesticides from various sources (Xavier et al. 2004). Eating pesticide-containing food products is associated with exposure levels that are around 103–105 times higher than consuming tainted drinking water or air , according to Sharma and Singhvi (2017).

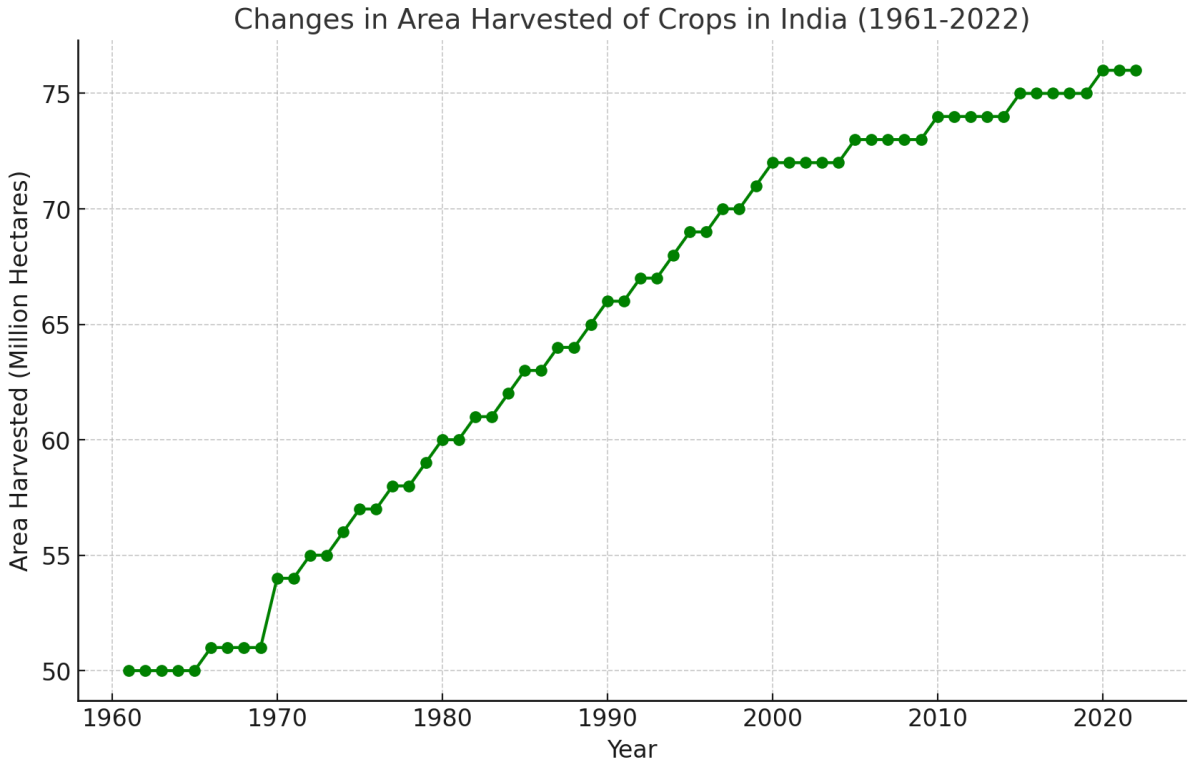

Fig. 1: Variations in the area of crops harvested between 1961 and 2022

(data source: FAOSTAT; FAO, 2024)

2.3. Crop Diversification after the 1990s

India's agricultural sector grew more market-oriented economic liberalization in the 1990s, which resulted in a wider variety of crops. Farmers started concentrating on more lucrative fruits, vegetables, horticultural crops, and export-oriented products like sugarcane and cotton. This change increased the area planted to high-value crops while decreasing the area collected for traditional mainstays like rice and wheat in some areas. The figure 1 illustrates the changes in area harvested of crops in India from 1961 to 2022. The x-axis on the graph represents the timeline in years spanning from 1960 to 2022 and y-axis shows the total area harvested in million hectares. This shows the significant increases occurred in the 1970s and 1980s, corresponding to India's Green Revolution, which expanded agricultural practices and irrigation. The growth rate slowed down after the 1990s, indicating stabilization in 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 closer to 50–55 million hectares, indicating slow growth. During 1970–1990, the dots rise steadily, showing a sharp increase due to agricultural expansion and policy reforms like in Green Revolution. Stabilization occurs during 1990–2022 as the dots become nearly horizontal after 1990, staying around 75 million hectares, suggesting a plateau in harvested area.

2.4. Immediate Effects of the Green Revolution

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

The following succinctly describes the main ecological and social effects of the Green Revolution: (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.

2.4.1.Impacts of pesticides on Farmers:

Because they are ignorant of the negative consequences of pesticides, most farmers who apply them do not use personal protective equipment (PPE), such as gloves, safety masks, etc. When pesticides are sprayed on plants, they can enter the body right away and cause blood nitrate levels, which render hemoglobin immobile.A lengthy period of exposure to organophosphates can 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 to bioaccumulation and cause severely harmful effects on humans, dichlorodiphenyltrichloroethane, or DDT, was a common pesticide in India but is now illegal globally (Sharma and Singhvi 2017). Women make up 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 thought to be a strong correlation between the overall number of birth defects and the concentration of agrochemicals in the water. In developing countries like India, agrochemicals have a larger negative impact on water (Brainerd and Menon 2014).

The excessive use of groundwater for irrigation 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.

2.4.2. Impacts of green revolution on Indigenous crops in India

Native types of crops are widely grown and well-known in their culture. The traditional meals and cereal-based products that were once a staple 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. The 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). The 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 a number of 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). The report by Kumbhar et al. (2015) 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 kinds. This research 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 region. 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, Himachal Pradesh's jatu rice are highly appreciated. Matali and Lal Dhan from Himachal Pradesh are used to cure fever and reduce hypertension. The Himalayan states of Uttar Pradesh and Himachal Pradesh are the origin of the well-known red rice variety Kafalya. It is utilized to cure 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 healthbenefits, while Varla Chennellu and Chuvannachennellu are consumed by menopausal, pubescent, and pregnant women because they lessen issues related to hormonal imbalances; Chuvannakunjinelu is boiled with water and given to people who are experiencing epileptic fits. The varieties of Kerala, such as Karinjan and Karimalakaran, are rich in fiber and are known to lower the risk of diabetes; Mundakan is consumed to increase stamina. (Nagarajan et al. 2018). Chhattisgarh and Jharkhand's Karhani is used as a tonic for 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 are yet 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) state that millet is resistant to diseases, pests, and drought. Compared to other cereals, millets have a relatively short growth season and require very little water for cultivation. Millets are used to make roti, dosai, kuzh (porridge), infant meals, ambali, wine, and health mix, as well as treats like murukku. Millets include polyphenols, which have anti-inflammatory and antioxidant properties (Chandrasekara et al. 2010). Because the whole grain has prebiotic effect, which raises 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 provide protection against heart disease, diabetes, obesity, and cancer. Although millets offer a number of health benefits, their anti-nutrients hinder the absorption of nutrients. Millets provide a number of health benefits, but their anti-nutrients hinder the absorption of nutrients.

2.5. Native Crop Varieties Are Going Extinct

India lost about 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 since they would grow faster (Taylor, 2019). This is seen in Figure 2. Wheat, soybeans, and rice are being farmed at significantly greater rates. Additionally, the output of other millets such as sorghum, barley, and groundnuts has significantly decreased.The availability of HYV seeds and the growth of the areas where these crops are produced were the causes of the increase in some crops. (Singh, 2019).Farmer's preferences also affected how they farmed their crops.Not any more than they had previously been, the natural oilseed crops such as mustard, sesame, and others, along with certain pulses like moong, gram, and tur, were farmed. Traditionally produced and eaten crops like millets may thrive in dry and semi-arid regions because of their low water requirements. But because there were no high-yielding millets available, farmers shifted to only planting rice and wheat (Srivastava et al., 2020).

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 time

It is clear from this research that the required steps should be taken to preserve the country's native species and to pass on knowledge to future generations by revitalizing the crops. All indigenous varieties' germplasm 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. Additionally, farmer enthusiasm, stakeholder-initiated administrative actions, and vendor marketing techniques are the main drivers of the resuscitation of indigenous crops. Furthermore, understanding the health advantages of native crops may help to save them from going extinct and guarantee that they will be available in local markets and cooking techniques for next generations.

2.6. Food Security in India

Greater accessibility to enough food at all times for everyone is known as food security (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). And only if we embrace sustainable agricultural methods will this be feasible. According to Kumar et al. (2018), the only profession that employs 40% of the world's workforce is

agriculture. 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, when food grain production is abundant but distribution is unequal, making it a problem that is not unique to any one nation. It is quite difficult to feed the growing population with wholesome food. A record-breaking state of food grain production is also brought on by crop failure from floods and droughts, declining water supplies, soil erosion, and climatic oddities. Another factor contributing to the agricultural problem 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 in order 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.

India's food security position was drastically changed by the Green Revolution effort in the late 1960s.For the past three to four decades, it has not only raised food grain output but also stimulated economic growth. Despite the high population growth, which nearly doubled over that time, it cut poverty and food insecurity by 50%. As a result, the nation is able to become a food-sufficient one. With a current population of 1394 million and growing, India requires a significant number of food grains. The current state of food security is good in terms of food availability, accessibility, and approachability as compared to the pre-Green Revolution state. The Green Revolution approach was implemented by the Indian government in an effort to increase food grain production in the nation 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 levelsdi. Food grain production has more than five times increased from 50.82 million tonnes in 1950–51 to approximately 284.95 million tonnes in 2020–21.

Additionally, the proportion of creals in the overall production of food grains has grown from 83.5 percent in 1950-51 to 91.8 percent in 2020-21, while the proportion of pulses has 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 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 production of other coarse grains and pulses has decreased. Surplus output often increases agriculture's share of the state gross domestic product and is traded to food-deficit states. Haryana ranks 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 a food security law introduced in parliament? This suggests that the nation does not have enough 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 only receive one meal per day and endure malnourishment and starvation.

2.7. The Need for Food Policy

The wellbeing of farmers is currently receiving increased attention from the Indian government. The establishment of a number of farmer welfare programs to enhance their financial circumstances and boost the agricultural industry. For the benefit of all Indian farmers, the government has so launched new plans, programs, initiatives, and projects. As a result, 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. As a result, 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 favourable climatic circumstances and sufficient and timely rainfall; therefore the scenario could not last for very long.

Drought, floods, and cyclones revealed the food grains crisis condition 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 going rate in the market through the network of fair pricing stores. In order 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 the 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 in order 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. The deteriorating soil degradation and water depletion may soon lead to food shortages again. Care should be taken while implementing new treatments to avoid interfering with other systems or causing problems in the future. 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 impact other links. Ecological harm is largely caused by human activity (Vaz et al. 2005). Agricultural pesticides are found in soil, surface water, and runoff, and they are released into the environment by leaching, runoff, and air drift. This could contaminate water, soil, and other plants. Almost all habitats including both marine and terrestrial animals have been shown to contain pesticide residues. (Choudhary et al. 2018). Among the ways are biomagnification or bioamplification, which occurs when contaminated food is consumed, and bioconcentration, which occurs when the substance is absorbed through the gills or teguments. High concentrations of persistent organic pollutants were 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, goat, and cattle, kills insects and plants, and poisons fish and birds. This can lead to bioaccumulation in humans, which will impair their overall health and nutrition in addition to 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 treble 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 grain kinds, like millets, shouldn't go extinct as a result of further advancements.

To sum up, 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 process should be guided by continuous evaluation of the benefits and drawbacks.

An already fragile food chain is impacted by the green revolution's consequences. Since they might alter the narratives of growth and prosperity, the possible disadvantages are rarely discussed. Long-term sustainability may be a concern for developments implemented out of need. Using organic farming systems is essential to sustainable agriculture operations. Similarly, alternative farming practices like intercropping and Zero Budget Natural Farming (ZBNF), which follows the core principles of promoting natural processes and eliminating external inputs, can be used (Khadse et al. 2018). The government of Karnataka and Andhra Pradesh (AP), two southern Indian states, plans to convert 6 million farmers and 8 million hectares of land under the state initiative of Climate Resilient Zero Budget Natural Farming, due to the positive outcomes of the ZBNF impact assessments in these states (Reddy et al. 2019; Koner and Laha 2020). Crop yields have reportedly climbed to 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 systems approach. The green revolution, for instance, was started in an attempt to mitigate the yield decline problem. There are presently plans for a second green revolution. There are presently plans for a second green revolution. Prior to putting such ideas into practice, environmental risk assessments and other studies are required. To secure a sustainable future, research should be conducted.

3. CONCLUSION

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 widened as wealthier farmers reaped disproportionate benefits, leaving smallholders burdened with debt and marginalized regions neglected. Moving forward, a more sustainable agricultural model must integrate the lessons of the Green Revolution. Policies should promote agroecological practices, diversify cropping systems to include nutrient-rich traditional crops, and ensure equitable access to resources. By balancing productivity with environmental stewardship and nutritional security, future agricultural reforms can avoid the pitfalls of the past while feeding a growing population sustainably. The challenge lies not just in increasing yield, but in ensuring that food systems are resilient, equitable, and health-conscious.

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