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Ploughing Progress, Preserving Nature: Agricultural Development and Environmental Sustainability in India-1968-69 to 2021-22

Dr. Nikhil Kumar Mandal

Associate Professor in Economics

Chakdaha College under Kalyani University

Nadia, West Bengal

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Abstract

Environmental degradation has become a major challenge in India due to the rapid expansion of agricultural activities and increasing pressure on natural resources. The need to ensure food security for a growing population has intensified agricultural production, resulting in greater use of land, water, fertilizers, and pesticides. This study examines the environmental implications of agricultural development in India by focusing on four key dimensions: cropping intensity, irrigation intensity, and the excessive use of chemical fertilizers and pesticides. The analysis is based on secondary data collected from the Ministry of Agriculture and Farmers Welfare, Government of India, covering the period from 1968–69 to 2021–22. Simple arithmetic techniques and Annual Average Compound Growth Rates (AACGRs) are used for analysis. The findings indicate that increasing cropping intensity contributes to soil degradation through nutrient depletion and loss of soil structure. Irrigation intensity shows an average annual growth rate of 0.45%, reflecting expanding irrigated agriculture, which supports multiple cropping but also intensifies pressure on soil and water resources, raising serious concerns for environmental sustainability.

Keywords: *Agricultural Development, Irrigation Intensity Cropping Intensity Fertilizer Consumption and sustainable environment*

Introduction

As humans have expanded worldwide, agriculture has emerged as the dominant land management system. The intensity of human impact on land is increasing with rapid population growth and growing food needs. Rapid human population growth, combined with competing demands for land, is intensifying land scarcity worldwide. As the need for food, housing, infrastructure, and economic development increases, natural and wild landscapes are increasingly converted into agricultural fields and other human uses. This transformation reduces natural habitats, alters ecosystems, and places additional pressure on limited land resources. The growing competition for land highlights the challenge of balancing agricultural expansion and development needs with environmental conservation and sustainable land.

Environmental degradation has emerged as one of the most pressing challenges in the contemporary world, and India is no exception. Rapid agricultural growth, rising population pressure, persistent poverty, and other socio-economic factors have significantly intensified stress on natural resources. In India, the need to ensure food security for a continuously growing population has led to an expansion and intensification of agricultural production. While this has contributed to higher output, it has also generated serious environmental consequences. To meet increasing demand, agricultural land is often used repeatedly without adequate fallow periods, leading to soil exhaustion, nutrient depletion, and declining soil fertility. Overexploitation of land beyond its natural regenerative capacity accelerates land degradation and reduces long-term agricultural productivity. At the same time, the excessive use of non-renewable natural resources such as groundwater has resulted in falling water tables and increased vulnerability to water scarcity in many regions.

Moreover, the widespread and often indiscriminate application of chemical fertilizers and pesticides has

further aggravated environmental degradation. Although these inputs initially enhance crop yields, their prolonged use contaminates soil and water bodies, reduces biodiversity, and poses risks to human and animal health. Chemical residues accumulate in ecosystems, disrupting natural processes and ecological balance. In this context, environmental degradation in India can largely be attributed to unsustainable land use practices, depletion of non-renewable resources, and the excessive dependence on chemical inputs in agriculture. Addressing these challenges requires a shift towards sustainable agricultural practices that balance productivity with environmental conservation.

Therefore, the impact of agriculture on the environment is a crucial subject for discussion, as it has become a pressing concern for human survival. Growing environmental stress threatens natural resources, food security, and human health, making sustainable agricultural practices essential for ensuring a balanced and livable future.

Literature review

R.B. Singh (2000), in his study "*Environmental Consequences of Agricultural Development: A Case Study from the Green Revolution State of Haryana, India*", examined the environmental impacts of agricultural intensification. While the Green Revolution ensured national food self-sufficiency, Haryana has experienced persistent environmental degradation. With nearly 82% of land already cultivated, further productivity depends on energy-intensive inputs. Declining nutrient-use efficiency, soil degradation, and inefficient water management limit yields, with about 60% of the area affected, posing serious risks to future food security and ecosystem sustainability.

Tiziano Gomiero et al. (2011) argued that modern agricultural systems generate significant environmental pressures that threaten long-term

sustainability. They highlighted key concerns such as soil erosion and declining soil fertility, rising water demand, contamination from excessive use of fertilizers and pesticides, loss of biodiversity due to land-use change, and increasing greenhouse gas emissions from farming activities. Although the Green Revolution greatly enhanced global food production and helped reduce hunger in many regions, the projected 70–100% increase in food demand by 2050 presents a formidable challenge. The world must produce more food with limited land, water, and energy resources while preserving ecological stability.

The authors emphasize that alternative, ecologically based farming systems—designed to reduce external inputs, conserve natural resources, and maintain soil health—offer viable pathways toward sustainability. However, technological advancement alone cannot resolve the crisis. Structural socioeconomic issues, including unequal access to land and resources, rapid population growth, and inadequate education, must also be addressed. Achieving sustainable agriculture for future generations therefore requires integrated innovation, supportive policies, and a fundamental shift toward environmentally responsible values and development models.

In *Nitrogen Challenges and Opportunities for Agricultural and Environmental Science in India*, edited by Engarcia Medejon (2021), the need for effective nitrogen stewardship is emphasized through legume–cereal crop rotations to enhance sustainability. The book highlights emerging technologies such as synthetic symbioses and plastic nitrogen fixation as potentially transformative, requiring careful evaluation. It also stresses sharing genetic diversity and innovations to reduce fertilizer use. Precision tools like leaf colour sensing, combined with urease inhibitors and improved residue management, could improve India's nitrogen use efficiency by 20–25 percent by 2030

Sewnet Getahun et al. (2024), in their systematic review “*Application of Precision Agriculture Technologies for Sustainable Crop Production and Environmental Sustainability*”, highlighted the transformative role of precision agriculture technologies in modern farming. Tools such as remote sensing, GPS-guided machinery, variable rate technology, and Internet of Things (IoT) devices enable efficient resource use. These technologies support environmental sustainability by conserving water, reducing chemical inputs, improving soil health, and lowering farming impacts, while simultaneously increasing crop productivity and profitability to meet rising global food demand.

Objectives

This paper examines the growing environmental concerns associated with agricultural development in India by focusing on four critical dimensions that challenge environmental sustainability. These dimensions include cropping intensity, irrigation intensity, the heavy consumption of chemical fertilizers and pesticides. Increased cropping intensity has placed severe pressure on soil health, leading to nutrient depletion, soil degradation, and declining long-term productivity. Rising water intensity, driven by expanded irrigation and water-intensive cropping patterns, has contributed to groundwater depletion and increasing water scarcity across several regions. Additionally, the excessive use of chemical fertilizers and pesticides has adversely affected soil quality, water bodies, and biodiversity, while also posing risks to human health. Together, these factors have intensified environmental stress, resulting in biodiversity loss and heightened vulnerability to climate change. The study highlights how these interlinked agricultural practices undermine the sustainability of the environment and emphasizes the urgent need for adopting sustainable agricultural practices to balance productivity growth with ecological conservation in India.

Methodology

This paper relies entirely on secondary sources of information. Data have been collected from the Ministry of Agriculture & Farmers Welfare, Government of India. The study covers a period of 54 years, from 1968–69 to 2021–22, capturing the long-term effects of the Green Revolution and subsequent developments in Indian agriculture. In addition to primary sources, this study draws on information from published books, academic journals, and other relevant literature. The paper examines four key dimensions that pose serious challenges to environmental sustainability in India: cropping intensity, irrigation intensity, and the excessive use of chemical fertilizers and pesticides. Among these, particular emphasis is placed on cropping intensity and water intensity. Cropping intensity is defined as the ratio of Gross Sown Area to Net Sown Area, reflecting the extent of multiple cropping on the same land within a year. A similar methodological approach is adopted to measure irrigation intensity, enabling a consistent assessment of resource pressure and sustainability concerns.

On the other hand, this study examines trends in fertilizer and pesticide consumption over time. Pesticides are commonly viewed as a quick, convenient, and cost-effective method for controlling weeds and insect pests, particularly in urban landscapes. However, their extensive use has led to widespread environmental contamination. Pesticide residues are now detected in soil and air, as well as in surface and groundwater across the country. Urban pesticide applications further intensify this problem, posing serious risks to environmental quality and long-term sustainability.

The analysis involves the use of simple arithmetic calculations to present findings, complemented by illustrative diagrams for clarity. Statistical tools have been used to compute the annual average compound

growth rates (AACGRs, henceforth), utilizing appropriate software for accurate results.

Growth rate is calculated as annual average compound growth rate (%). The annual average compound growth rate is calculated using a semi-logarithmic stochastic regression equation: $\text{Log}(y_t) = a + bt + u$, where y_t is dependent variable, t =year, and u =stochastic disturbance terms. Then, the growth rate (g) is estimated as $g = (e^{b^*} - 1) * 100$, where b^* is the least-square estimate by using usual statistical tools. In our model, the three dependent variables are the percentage of cropping intensity, irrigation intensity and consumption of fertilisers (N+P+K), Kg per hectare

Agricultural Development and Environmental Sustainability

The concept of *sustainability* is widely used by environmentalists to emphasize the need for a careful and desirable balance between economic development and environmental protection. Growing concern about sustainability arises because long-term economic growth, human well-being, and the overall quality of life are closely linked to the health, availability, and resilience of environmental resources. To sustain the environment, certain economic activities that exert excessive pressure on natural resources need to be curtailed, while new activities must be introduced to prevent environmental degradation and to restore damaged ecosystems to their original or near-original condition. With regard to the environmental consequences of economic growth, a common pattern has emerged in recent years. In the initial stages of economic development, growth is typically

accompanied by environmental deterioration due to intensive resource use, pollution, and weak regulatory frameworks. However, at more advanced stages of development, rising per capita income increases public awareness and demand for a cleaner environment. At this stage, economies are better positioned to allocate financial resources toward pollution control, cleaner technologies, environmental conservation, and sustainable development initiatives.

Environmental Impacts of Agricultural Development in India

This section critically examines how agricultural development has affected the environment, divided into sub-sections- a. percentage of cropping intensity b. percentage of irrigation intensity and c. consumption of fertilisers (N+P+K), Kg per hectare. Cropping intensity (%) leads to Environmental Deterioration. It means that Soil Degradation means repeated cultivation exhausts soil nutrients such as nitrogen, phosphorus, and potassium; continuous tillage breaks down soil structure, leading to loss of soil organic matter; soil becomes compacted and more prone to erosion by wind and water.

Percentage of cropping intensity

Table 1 presents the distribution of cropping intensity (%) and irrigation intensity (%) in India's agricultural sector during the period 1968–69 to 2021–22. The analysis reveals that cropping intensity recorded an average growth rate of 0.56 % over the study period, indicating a gradual intensification of land use. Higher cropping intensity implies that multiple crops are cultivated successively on the same parcel of land within a year, which, if not supported by sustainable

practices, often results in soil nutrient depletion and land degradation. The level of cropping intensity increased from 116.18 % in 1968–69 to 122.25 % in 1978–79 and further rose to 128.47 % in 1988–89. This upward trend continued in the subsequent decades, reaching 134.26 % in 1998–99 and 137.65 % in 2008–09. By 2021–22, cropping intensity had increased substantially to 155.42 %. Overall, the figures clearly indicate a sustained and broad-based rising trend in cropping intensity in Indian agriculture over the last five decades, reflecting both increased production pressure on land resources and growing environmental concerns.

Percentage of irrigation intensity

Irrigation intensity has emerged as one of the most significant drivers of environmental deterioration in the agricultural sector. In the post–Green Revolution period, the growing

demand for agricultural products has encouraged farmers to cultivate multiple crops on the

same parcel of land within a year, leading to increased dependence on groundwater resources. Although higher irrigation intensity has contributed substantially to enhanced agricultural productivity and food security, its unregulated expansion has resulted in serious environmental consequences. Excessive groundwater extraction has caused a sharp decline in water tables, while continuous irrigation has accelerated soil degradation and salinization. Moreover, intensive irrigation practices have promoted the overuse of chemical fertilizers and pesticides, leading to soil and water pollution and disturbing ecological balance, thereby intensifying overall environmental deterioration.

Table 1 : The Year wise distribution of cropping intensity (%), Irrigation intensity (%) and consumption fertilisers its annual growth rate in India during 1968-69 to 2021-22.						
Year	Cropping Intensity	Annual growth rate	Irrigation intensity	Annual growth rate	Consumption of Fertilisers (N+P+K), Kg per hectare)	Annual growth rate
1968-69	116.18	122.30	12.82
1969-70	116.93	0.65	122.42	0.09	14.27	11.32
1970-71	118.19	1.08	122.83	0.34	15.54	8.92
1971-72	118.23	0.03	121.81	-0.83	19.04	22.50
1972-73	118.24	0.01	122.71	0.75	20.20	6.09
1973-74	119.27	0.88	123.75	0.84	19.94	-1.27
1974-75	119.16	-0.10	123.82	0.06	18.65	-6.47
1975-76	120.93	1.49	125.35	1.24	20.40	9.39
1976-77	119.97	-0.80	123.90	-1.16	24.45	19.83
1977-78	121.33	1.14	126.07	1.76	30.22	23.62
1978-79	122.25	0.76	126.93	0.68	35.81	18.49
1979-80	122.10	-0.13	127.75	0.65	37.87	5.75
1980-81	123.31	0.99	128.56	0.64	39.43	4.12
1981-82	124.53	0.99	126.94	-1.26	42.70	8.29
1982-83	123.20	-1.07	127.38	0.35	45.57	6.73
1983-84	125.71	2.04	128.30	0.72	53.98	18.44
1984-85	125.15	-0.44	129.37	0.84	58.27	7.96
1985-86	126.66	1.20	129.64	0.21	60.11	3.16
1986-87	126.39	-0.21	130.98	1.04	61.97	3.09
1987-88	127.33	0.75	130.66	-0.25	65.48	5.66
1988-89	128.47	0.89	132.46	1.38	77.81	18.83
1989-90	128.05	-0.32	132.44	-0.01	81.28	4.47
1990-91	129.89	1.43	131.61	-0.63	87.76	7.97
1991-92	128.67	-0.94	131.70	0.07	89.88	2.42
1992-93	130.11	1.12	132.75	0.80	85.20	-5.21
1993-94	131.08	0.74	132.96	0.16	86.90	2.00
1994-95	131.54	0.35	133.30	0.26	94.85	9.14

1995-96	131.84	0.22	133.61	0.23	97.61	2.91
1996-97	132.58	0.57	137.96	3.25	100.12	2.57
1997-98	133.84	0.95	137.06	-0.65	114.05	13.92
1998-99	134.26	0.31	136.96	-0.07	117.69	3.19
1999-00	133.56	-0.52	137.70	0.54	128.10	8.85
2000-01	131.13	-1.82	138.03	0.23	118.15	-7.76
2001-02	133.60	1.88	137.64	-0.28	123.36	4.40
2002-03	131.79	-1.35	135.55	-1.52	121.95	-1.14
2003-04	134.79	2.27	136.77	0.90	119.39	-2.10
2004-05	135.88	0.81	136.89	0.09	130.83	9.58
2005-06	136.54	0.49	138.53	1.20	144.09	10.14
2006-07	137.59	0.77	138.27	-0.19	154.84	7.46
2007-08	138.43	0.61	139.36	0.79	160.05	3.36
2008-09	137.65	-0.56	139.69	0.24	175.55	9.68
2009-10	135.94	-1.24	137.35	-1.67	190.34	8.43
2010-11	140.15	3.10	139.85	1.82	198.91	4.50
2011-12	138.89	-0.90	139.27	-0.41	197.39	-0.77
2012-13	139.15	0.18	139.33	0.05	182.75	-7.41
2013-14	142.52	2.43	140.70	0.99	173.32	-5.16
2014-15	142.19	-0.24	142.68	1.40	183.43	5.83
2015-16	142.56	0.26	144.24	1.09	192.49	4.94
2016-17	144.72	1.51	143.81	-0.29	186.69	-3.01
2017-18	144.76	0.03	144.63	0.56	191.61	2.64
2018-19	145.32	0.39	144.95	0.22	197.78	3.22
2019-20	151.08	3.96	148.99	2.79	209.94	6.15
2020-21	152.68	1.06	153.00	2.70	229.90	9.51
2021-22	155.42	1.79	154.49	0.97	211.33	-8.08
Average Growth Rate		0.56		0.45		5.68

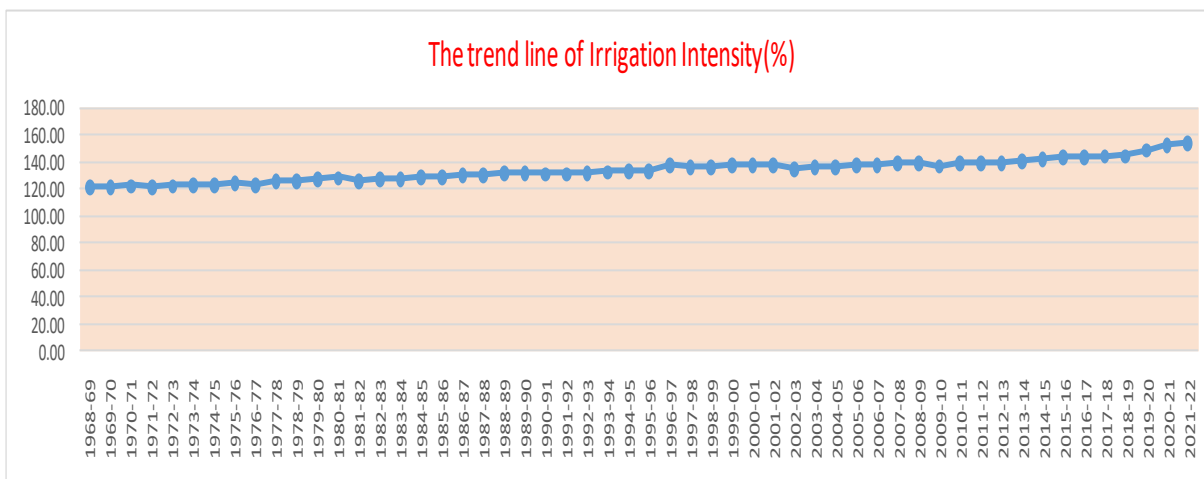
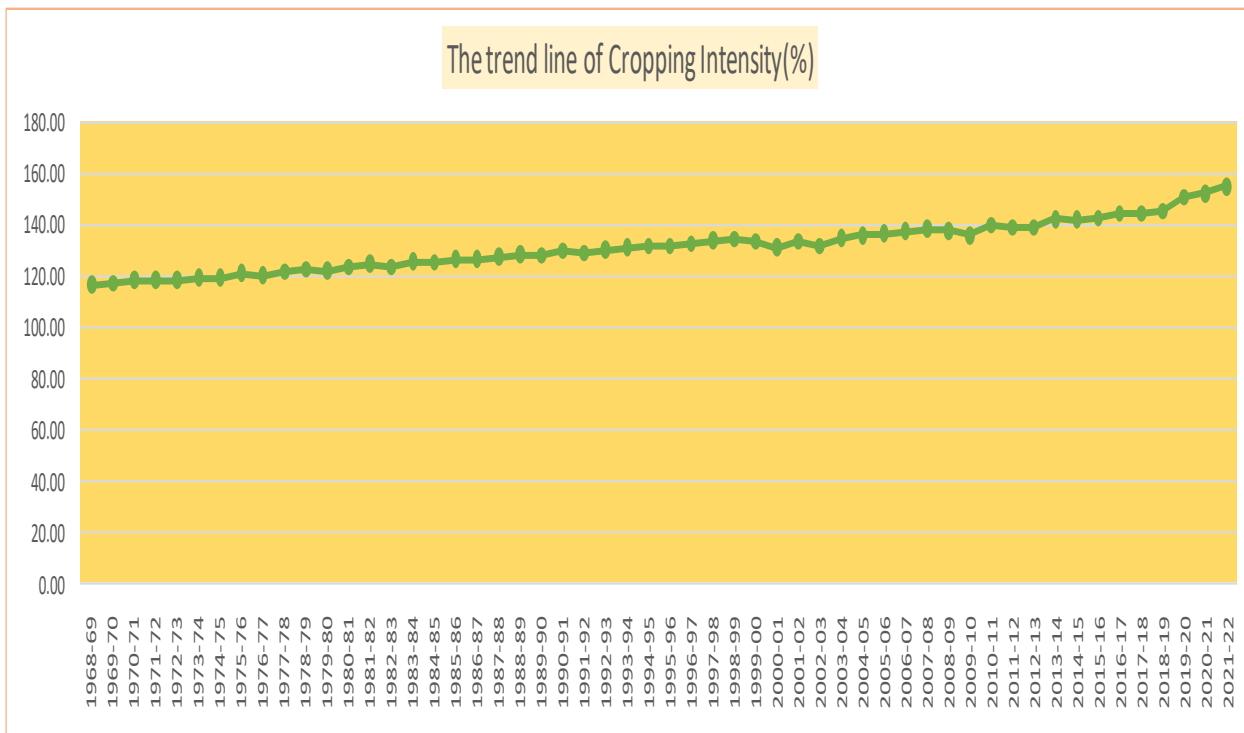
Table 1 shows the distribution of irrigation intensity in the agricultural sector of India over the period from 1968–69 to 2021–22. The analysis reveals that irrigation intensity recorded

an average annual growth rate of 0.45 % during the study period, indicating a steady expansion of irrigated cropping practices. Higher irrigation intensity enables

farmers to cultivate multiple crops successively on the same land within a year; however, such intensive use often leads to adverse environmental outcomes, particularly soil degradation. The level of irrigation intensity increased from 122.30 % in 1968–69 to 126.93 % in 1978–79 and further rose to 132.46 % in 1988–89. This upward trend continued, reaching

136.96 % in 1998–99 and 139.69 % in 2008–09. By 2021–22, irrigation intensity had increased substantially to 154.49 %. Overall, the data clearly

indicate a persistent and broad-based rising trend in irrigation intensity over the years, reflecting both intensified agricultural practices and



growing pressure on natural resources. Rising trend in irrigation intensity over the years is shown in the diagram 2.

Annual average compound growth rate for cropping intensity (%) and irrigation intensity (%) and consumption fertilizer: Table 2 examines the compound annual average growth rates (AACGRs, hereafter) of two important indicators of agricultural

development, namely percentage cropping intensity and percentage irrigation intensity, over the period from 1968–69 to 2021–22. The table reports the long-term growth trends of these variables, which reflect changes in land-use intensity and the expansion of irrigation facilities in agriculture. The results show that percentage cropping intensity recorded an AACGR of 0.45 percent, while percentage irrigation intensity

grew at an AACGR of 0.36 percent during the study period. The compound average growth rate of fertilizer consumption was estimated at 5.32 percent during the study period. This indicates that the consumption of fertilizers increased steadily at an average annual rate of 5.32 percent over time. The positive growth rate reflects a continuous rise in the use of fertilizers, which may be attributed to the adoption of modern

agricultural practices, increased cultivation intensity, and the growing need to enhance agricultural productivity. These positive growth rates indicate a sustained increase in agricultural activity and suggest that agricultural output has been rising over time. All estimated AACGRs are statistically significant at the 1 percent level, confirming the robustness of the observed trends.

Irrigation Intensity and consumption fertilizer for the period 1968-69 to 20				
		Cropping Intensity	Irrigation Intensity	Consumption fertilizer
Compound Average Growth Rate		0.45	0.36	5.32
R Square		0.96	0.95	0.93
Adjusted R Square		0.96	0.94	0.93
P-value	Intercept	0.00	0.00	0.00
	T	0.00	0.00	0.00
F		1354.80	889.09	688.62

However, while the increasing cropping and irrigation intensities signal progress in agricultural production, they also raise important concerns regarding environmental sustainability. Continuous intensification of land use may lead to declining soil productivity over time. To maintain or enhance output levels, farmers often rely heavily on chemical fertilizers and pesticides. Excessive use of these inputs can degrade soil health, contaminate water resources, and contribute to large-scale environmental pollution. Therefore, although the growth in these agricultural indicators reflects improved production performance, it also highlights the need to balance agricultural expansion with sustainable practices to minimize adverse environmental impacts in the long run.

Conclusion:

The analysis of agricultural development indicators in India from 1968–69 to 2021–22 reveals a continuous increase in cropping intensity, irrigation intensity, and fertilizer consumption, reflecting the growing intensification of agricultural practices in the country. Irrigation intensity increased steadily from 122.30

percent in 1968–69 to 154.49 percent in 2021–22, indicating the expansion of irrigated agriculture and improved access to irrigation facilities. Similarly, cropping intensity and irrigation intensity recorded positive AACGRs of 0.45 percent and 0.36 percent respectively, while fertilizer consumption grew at a much higher annual rate of 5.32 percent during the study period. These statistically significant growth rates confirm that agricultural production activities have expanded consistently over time.

The findings suggest that Indian agriculture has become increasingly dependent on intensive cultivation methods to meet the rising demand for food and enhance productivity. Greater irrigation coverage and multiple cropping practices have enabled farmers to utilize land more efficiently and increase output levels. However, the study also highlights important environmental concerns associated with this rapid agricultural intensification. Continuous use of land, combined with excessive application of chemical fertilizers and pesticides, may lead to soil degradation,

declining soil fertility, water contamination, and ecological imbalance in the long run.

Therefore, while the observed growth trends indicate progress in agricultural development and productivity enhancement, they also emphasize the urgent need for sustainable agricultural practices. Adoption of balanced fertilizer use, efficient irrigation management, organic farming methods, and soil conservation measures is essential to maintain long-term agricultural productivity while minimizing environmental degradation and ensuring sustainable development.

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