Cropping Intensity, Irrigation, and Fertilizer Consumption: An Analysis

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Abstract
The study examined the trends and relationships between cropping intensity, irrigation, and fertilizer consumption in India from 2004 to 2021. The primary objectives include analyzing trends in cropping intensity and investigating how irrigation area and fertilizer consumption influence cropping intensity. The results demonstrated a general upward trend in cropping intensity, increasing from 135.9 per cent in 2004-05 to 152.7 per cent in 2020-21, with notable growth during specific years. Irrigation infrastructure also saw substantial growth, particularly from 2010 onwards, reflecting government efforts to improve water-use efficiency and agricultural productivity. Fertilizer consumption fluctuated but generally increased, with significant rises in the mid-2000s and early 2020s. Empirical analysis through regression modeling showed a positive and significant relationship between gross irrigated area and cropping intensity, while fertilizer consumption negatively impacted cropping intensity. Diagnostic tests confirmed the reliability of the model, with no multicollinearity or autocorrelation. Overall, the findings suggested that while irrigation expansion contributes positively to cropping intensity, there is a need for balanced fertilizer use to maintain sustainable agricultural practices.

Keywords: Cropping Intensity, Irrigation, Fertilizer Consumption, Agricultural Productivity, India, Land Use Trends

Introduction

Agriculture has long been a crucial part of India's economy, influencing the livelihoods of millions and contributing significantly to the national GDP. Over time, factors like technological progress, government policies, and environmental changes have shaped land use patterns and agricultural inputs. Among the key factors affecting agricultural productivity are cropping intensity, irrigation, and fertilizer consumption. This study focused on the trends and relationships between these elements in India from 2004 to 2021, examining how irrigation infrastructure and fertilizer use influence cropping intensity.Cropping intensity, the ratio of cropped area to net sown area, indicates land use efficiency in agriculture. The government has worked to enhance cropping intensity through initiatives like the National Mission for Sustainable Agriculture (NMSA) and investments in irrigation.

Review of Literature

Agriculture in India has undergone significant transformations, with key developments in land use, cropping intensity, and modern agricultural practices. Cropping intensity, a measure of the ratio of area sown to net sown area, has steadily increased from 1950 to 2010, driven by technological advancements, the Green Revolution, and government initiatives, as documented by **Kumar et al. (2017).** This increase has enhanced food production and agricultural productivity, particularly in regions like Punjab and Haryana.Irrigation has been vital in facilitating multiple cropping cycles and boosting agricultural productivity. Bhattacharyya and **Jha (2018)** emphasize the role of expanded irrigation infrastructure, particularly after the Green Revolution, in enhancing cropping intensity, with regions like the Indo-Gangetic Plains seeing higher yields and multiple cropping seasons. However, unsustainable groundwater extraction in states like Punjab raises concerns about long-term sustainability.Fertilizer consumption has also been critical in India's agricultural growth, particularly following the adoption of high-yielding seed varieties. **Raghunandan et al. (2016)** highlight its role in increasing crop productivity, especially in the northern and western regions. However, excessive and imbalanced fertilizer use has led to environmental challenges, including soil degradation and water pollution. **Yadav and Singh (2018)** advocate for sustainable practices like integrated nutrient management (INM) to address these concerns.The synergy between irrigation and fertilizer use is crucial for cropping intensity. **Sharma et al. (2015)**notes that regions with efficient irrigation and balanced fertilizer application achieve the highest productivity gains, though regional agro-climatic conditions affect their effectiveness**.** **Patel and Mehta (2020)** caution against excessive fertilizer use, which can lead to diminishing returns, underscoring the importance of judicious application alongside efficient irrigation.Policy frameworks have supported sustainable agricultural practices, focusing on irrigation and fertilizer use. Programs like the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) and the National Mission for Sustainable Agriculture (NMSA) promote efficient water use and balanced fertilizer application. **Agarwal (2019)** underscores that the future of Indian agriculture depends on improving irrigation efficiency, conserving water, and ensuring the sustainability of fertilizer use.

Objectives of the Study

1. To study the trends in cropping intensity in India from 2004 to 2021.
2. To analyze the relationship between irrigation area and fertilizer consumption on cropping intensity in India.

Scope of the study

The study has conducted through the secondary data analysis. And it will help to policy makers to evaluated

Methodology

The study employed an econometric approach to analyze the determinants of cropping intensity in India using time-series data from 2004-05 to 2020-21. The primary variables include cropping intensity (dependent variable), gross irrigated area, and fertilizer consumption (independent variables). The regression model is specified as:

$$CI_t = \beta_0 + \beta_1 GIA_t + \beta_2 FC_t + \epsilon_t$$

where CI_t is cropping intensity, GIA_t is gross irrigated area, FC_t is fertilizer consumption, β_0 is the intercept, β_1 *and* $\beta_2$are coefficients, and ϵ_t is the error term.

The model is estimated using Ordinary Least Squares (OLS). Diagnostic checks include the Durbin-Watson test for autocorrelation and Variance Inflation Factor (VIF) for multicollinearity. The statistical significance of the results is evaluated using t-tests and F-tests, ensuring robustness and reliability.

Empirical Discussion

Table 1 Pattern of Land use in India - Cropping Intensity

S. N	Year	Cropping Intensity as per cent	AGR
1	2004-05	135.9	-
2	2005-06	136.5	0.44
3	2006-07	137.6	0.81
4	2007-08	138.4	0.58
5	2008-09	137.7	-0.51
6	2009-10	135.9	-1.31
7	2010-11	139.6	2.72
8	2011-12	138.9	-0.50
9	2012-13	139.1	0.14
10	2013-14	142.5	2.44
11	2014-15	142.2	-0.21
12	2015-16	142.6	0.28
13	2016-17	144.7	1.47
14	2017-18	144.8	0.07
15	2018-19	145.3	0.35
16	2019-20	151.1	3.99
17	2020-21	152.7	1.06

Source: RBI Report

As presented in the Table 1, the data on cropping intensity in India from 2004-05 to 2020-21 reveals a general upward trend, with the cropping intensity increasing from 135.9 per cent in 2004-05 to 152.7 per cent in 2020-21. This indicated that the frequency of crop cultivation, or the extent of land being cropped in multiple seasons, gradually increased over the years. The Annual Growth Rate (AGR), which represents the year-on-year change in cropping intensity, fluctuated across the years. Positive AGRs were recorded in most years, with notable peaks in 2010-11 (2.72 per cent), 2013-14 (2.44 per cent), and 2019-20 (3.99 per cent), which suggested periods of significant growth in cropping intensity

However, the data also highlighted certain years with negative AGR, such as 2008-09 (-0.51 per cent) and 2009-10 (-1.31 per cent), which could be attributed to factors like adverse climatic conditions or economic challenges in the agricultural sector. The low AGR of 0.07 per cent in 2017-18 indicates minimal change, possibly due to stable agricultural practices or less favorable environmental factors.

The overall upward trend in cropping intensity, especially in the later years, may reflect improvements in agricultural practices, the expansion of irrigation, and the implementation of government programs like the National Mission for Sustainable Agriculture (NMSA). This long-term increase in cropping intensity is also an indicator of enhanced productivity and the potential for greater food security in India **(RBI Report, 2020)[1].**

Table 2 Pattern of Land use in India- Gross Irrigated Area (Thousand Hectares)

S. N	Year	Gross Irrigated Area	AGR
1	2004-05	81078	-

[1]Reserve Bank of India (RBI). (2020). *Annual Report*.

2	2005-06	84279	3.95
3	2006-07	86752	2.93
4	2007-08	88057	1.50
5	2008-09	88895	0.95
6	2009-10	85087	-4.28
7	2010-11	88940	4.53
8	2011-12	91786	3.20
9	2012-13	92780	1.08
10	2013-14	96270	3.76
11	2014-15	97846	1.64
12	2015-16	97754	-0.09
13	2016-17	99620	1.91
14	2017-18	101467	1.85
15	2018-19	104711	3.20
16	2019-20	112443	7.38
17	2020-21	118934	5.77

Source: RBI Report

As depicted in the Table 2, indicated fluctuations in the total area under irrigation, measured in thousand hectares, along with the Annual Growth Rate (AGR). In 2004-05, the gross irrigated area was 81,078 thousand hectares, and the AGR was not applicable for that year. The following years show varying growth patterns in irrigation.

The period from 2005-06 to 2008-09 saw positive AGR, with significant increases in the gross irrigated area, especially in 2005-06 (3.95 per cent) and 2006-07 (2.93 per cent), indicating an expansion of irrigation infrastructure. However, in 2009-10, a decline of -4.28 per cent in AGR was recorded, reflecting a possible reduction in irrigation coverage, possibly due to weather-related disruptions or policy-related challenges.

The years 2010-11 to 2014-15 show a rebound in the growth rate, with an average AGR of around 3.0 per cent. Notably, 2019-20 had the highest AGR at 7.38 per cent, signaling a major expansion in the irrigated area, likely due to government initiatives aimed at increasing irrigation capacity and promoting water-use efficiency. After that, the AGR stabilized in 2020-21 at 5.77 per cent, marking a continued, steady growth in irrigation.

This overall upward trend in gross irrigated area is indicative of the government's ongoing efforts to improve irrigation facilities, enhance agricultural productivity, and secure water resources for farming, which are critical to ensuring food security and sustainable agricultural development in India **(RBI Report, 2020)[2].**

Table 3 Per Hectare Consumption of Fertiliser (N+P+K) (Kg. Per Hectare)

S. N	**Year**	**Consumption of Fertiliser**	**AGR**
1	2004-05	94.5	-
2	2005-06	104.5	10.58
3	2006-07	112.3	7.46
4	2007-08	115.3	2.67
5	2008-09	127.2	10.32

[2]Reserve Bank of India (RBI). (2020). *Annual Report*.

6	2009-10	135.3	6.37
7	2010-11	146.3	8.13
8	2011-12	142.3	-2.73
9	2012-13	130.8	-8.08
10	2013-14	118.5	-9.40
11	2014-15	127.5	7.59
12	2015-16	130.7	2.51
13	2016-17	124.4	-4.82
14	2017-18	127.9	2.81
15	2018-19	132.1	3.28
16	2019-20	127.8	-3.26
17	2020-21	137.2	7.36

Source: RBI Report

As shown in the table3, revealed significant variations in fertilizer usage across the years, with fluctuations in the Annual Growth Rate (AGR). In 2004-05, the per hectare consumption was 94.5 kg, and no AGR was reported for that year. Subsequently, there was a steady increase in fertilizer consumption until 2008-09, with the highest AGR of 10.58 per cent in 2005-06, indicating a notable rise in the use of fertilizers during that period.

From 2009-10 to 2013-14, the data shows an inconsistent trend in fertilizer consumption. There were significant decreases in fertilizer usage, particularly in 2012-13 and 2013-14, with AGR values of -8.08 per cent and -9.40 per cent, respectively. These declines could be attributed to various factors, including changes in agricultural practices, government policies, or challenges in fertilizer availability or affordability.

The years 2014-15 to 2019-20 indicate a recovery and stabilization in fertilizer consumption, with the AGR ranging from 2.51 per cent to 7.59 per cent. However, in 2019-20, a decline of -3.26 per cent in AGR was noted, which may reflect a temporary reduction in fertilizer consumption due to economic factors, policy changes, or shifts in agricultural inputs.

By 2020-21, the per hectare fertilizer consumption increased to 137.2 kg, with an AGR of 7.36 per cent, suggesting a renewed growth in fertilizer use, likely reflecting efforts to support agricultural productivity and sustainability in response to increasing food production demands. This upward trend in fertilizer consumption underscores the continuing reliance on fertilizers to boost crop yields, although it also highlights the need for balanced fertilizer management to avoid negative environmental impacts **(RBI Report, 2020).**

Regression Analysis

Table 4 Model Summary

R-value	**0.995**
R square	**0.9899**
F -value	**196.98**
P -value	**0.0001**

As reported in the Table 4, highlighted the exceptional strength and reliability of the regression analysis. The correlation coefficient (R-value) is 0.995, indicating a very strong positive relationship between the dependent variable (Crop Intensity) and the independent variables. Furthermore, the R square value of 0.9899 revealed that 98.99 per cent of the variation in Crop Intensity is explained by the independent variables included in the model. The F-value of 196.98, with a highly significant P-value of 0.0001, demonstrated that the overall model is statistically significant and provides a robust fit to the data. This indicates that the predictors collectively explain Crop Intensity effectively.

Table 5 Regression Analysis

Dependent Variable: Crop Intensity

Variable	Coefficient	Std.Error	T-value	P-Value
Gross Irrigated Area	0.41154	0.024183	17.02	0.000
Consumption of Fertiliser	-0.18558	0.057615	-3.22	0.032
Constant	1.131526	0.23516	4.81	0.009

Source: Computed

As depicted the Table 5, the regression analysis provided insights into the relationship between the independent variables and Crop Intensity. Gross Irrigated Area has a positive and statistically significant effect on Crop Intensity, with a coefficient of 0.41154 (P-value = 0.000). This indicated that for every unit increase in Gross Irrigated Area, Crop Intensity increases by 0.41154 units, holding other factors constant. Conversely, the Consumption of Fertilizer has a negative and statistically significant relationship with Crop Intensity, with a coefficient of -0.18558 (P-value = 0.032).

Table 6 Diagnostic Checking

Hypothesis	Test value	Decision
H0: There is no multicollinearity among the independent variables.	Mean VIF= 1.72	Accepted H_0
H0:There is no autocorrelation in the residuals of the regression model.	d= 2.060304	Accepted H_0

Source: Computed

As presented in the Table6,the results of diagnostic tests conducted to ensure the reliability of the regression model. The Variance Inflation Factor (VIF) was used to test formulticollinearity among the independent variables. With a mean VIF value of 1.72, which is below the commonly accepted threshold of 10, the test confirms the absence of significant multicollinearity, leading to accept the null hypothesis (H0) that multicollinearity is Absent.

Another test called Durbin-Watson statistic (d = 2.060304) was employed to detect autocorrelation in the residuals. The test value is close to the ideal value of 2, indicating no significant autocorrelation in the residuals, and thus the null hypothesis (H0) of no autocorrelation is also accepted.

Conclusion

It was found that Cropping intensity generally increased over the years, and reflecting an upward trajectory in land utilization, with a notable surge in the gross irrigated area and significant trends in the agricultural sector. Additionally, fertilizer consumption showed fluctuations, but overall, it aligned with efforts to enhance agricultural productivity. These findings were consistent with previous studies, which suggested that improved irrigation and efficient fertilizer use were crucial for India's agricultural growth and food security **(RBI Report, 2020; Sharma & Kumar, 2019).** The regression analysis further confirmed that the gross irrigated area positively influenced cropping intensity, while fertilizer consumption negatively impacted it, highlighting the need for balanced agricultural inputs.

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