Crop Area Dynamics And Irrigation Growth In Indian Agriculture

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Abstract

This research examines the patterns of crop diversification in India by looking at crop trends in total and irrigated areas over a period of two decades. The research uses information from Agricultural Statistics at a Glance 2023 to assess the size of crops and the level of crop diversification using the Simpson Diversity Index (SDI). Looking at trends and graphs shows where crop distribution has changed the most. We used both descriptive statistics and correlation analysis to analyse how much irrigation affects crop diversification. Results show that there are bigger differences in the use of crops between irrigated and unirrigated areas, and this difference is driven by more diversification in unirrigated areas. It was found that more irrigation is linked to more crop diversity, so irrigation development might support a variety of crops. These findings can be used to help create policies that support sustainable farming and wise water usage.

Keywords: *Crop diversification; Irrigation intensity; Simpson Diversity Index; Trend analysis; Agricultural statistics; India*

1. Introduction

Agriculture remains central to India's food security, rural livelihoods, and economic development, with a majority of the population reliant on farming. In this context, the sustainable management of land and water resources is increasingly vital. Crop diversification—the cultivation of a broader mix of crops rather than a dependence on a few staples has emerged as a key strategy to enhance resilience and optimize resource use.

The availability of irrigation plays a decisive role in influencing cropping patterns. While irrigated regions support intensive and high-value crop cultivation due to consistent water access, rain-fed areas remain more vulnerable to climatic variability and tend to exhibit more diverse, risk-averse crop choices. Analyzing how cultivated areas are distributed across these zones and how these patterns have evolved is essential for guiding climate-adaptive and evidence-based agricultural policy.

This study examines two decades of crop-wise area trends in India using secondary data, distinguishing between irrigated and unirrigated regions. By applying the Simpson Diversity Index (SDI), it quantifies the extent of crop diversification over time and explores its relationship with irrigation intensity. The results offer valuable insights into the spatial and temporal dynamics of crop distribution, contributing to a deeper understanding of irrigation's role in shaping sustainable land use and agricultural diversification.

2. Literature Review

Existing literature underscores the pivotal role of irrigation in shaping cropping patterns and promoting diversification in Indian agriculture. Sawant (1975) cautioned that irrigation statistics alone may not reflect land use intensity, advocating for localized analysis. Later studies (Nagpure et al., 2017; Sonawane et al., 2022) highlighted irrigation's

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role in reducing climatic risks and enabling high-value crops. Meena et al. (2016) stressed irrigation's importance in water-scarce areas, though optimal levels remain underexplored. While indices like the Herfindahl Index have been used (Sharma, 2019; Singh et al., 2013), many studies failed to differentiate irrigated and rain-fed systems. Earlier work (Gupta & Tewari, 1985; Ghosh, 2011) lacked updated crop-level insights. Recent spatial studies (Kumar et al., 2024; Gautam & Sangwan, 2021) acknowledged irrigation's influence but missed crop-specific temporal patterns. Mondal and Sarkar (2021) confirmed irrigation's effect on cropping intensity at the local level. This study addresses these gaps by conducting a disaggregated, crop-wise, time-series analysis of irrigated and rain-fed area patterns across India.

3. Objectives of Study

- To analyze the distribution of cultivated area and crop area shifts under irrigated and rain-fed conditions in India.
- To examine the relation between irrigation intensity and crop diversification

4. Hypothesis:

H11: There is a significant shift in crop cultivation from food grains to cash crops
H21: There is a significant relation between irrigation intensity and crop diversification.

5. Methodology

This research relies on secondary data obtained from the *Agricultural Statistics at a Glance 2023*, Government of India (GoI). The dataset includes statistics on selected major crops such as Rice, Wheat, Maize, Jowar, Bajra, Gram, Tur (Arhar), Groundnut, Rapeseed & Mustard, Cotton, and Sugarcane, spanning a period from 2002-03 to 2021-22. The data covers the area (in million hectares) under each crop, along with the percentage of irrigated area. Using this data, irrigated and rainfed areas in million hectares were calculated, and the irrigation intensity was derived using the formula:

$$Irrigation\ Intensity\ (\%) = \left(\frac{Total\ Irrigated\ Area}{Total\ Cropped\ Area}\right) \times 100$$

Crop shifts were assessed by calculating the percentage changes in area between crops during the study period.
Crop diversity was examined using the Simpson Diversity Index

$$SDI = 1 - \sum_{i=1}^{n} (\frac{A_i}{A_T})^2$$

where A_i represents the area under the i-th crop, and A_T is the total cropped area.

This index was computed annually for total, irrigated, and unirrigated agricultural land to measure crop diversification. To explore the relationship between irrigation availability and crop diversification, Pearson's Product-Moment Correlation Coefficient was calculated.

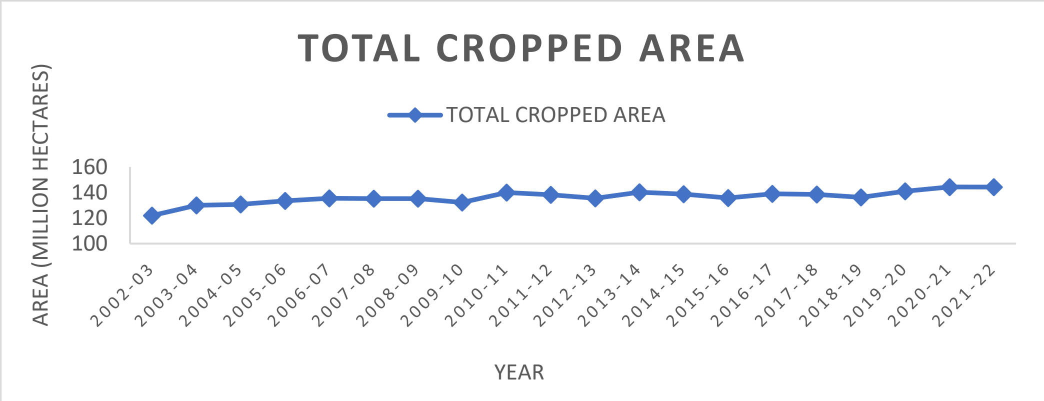
R software was explored for correlation studies and graphical representation of the relationship between irrigation intensity and crop diversification variability across total, irrigated, and unirrigated areas.

6. Findings

The study reveals several important trends and patterns in the context of crop area, irrigation dynamics, crop shifts, and diversification over a 20-year period in India:

6.1 Total Cropped Area Trends:

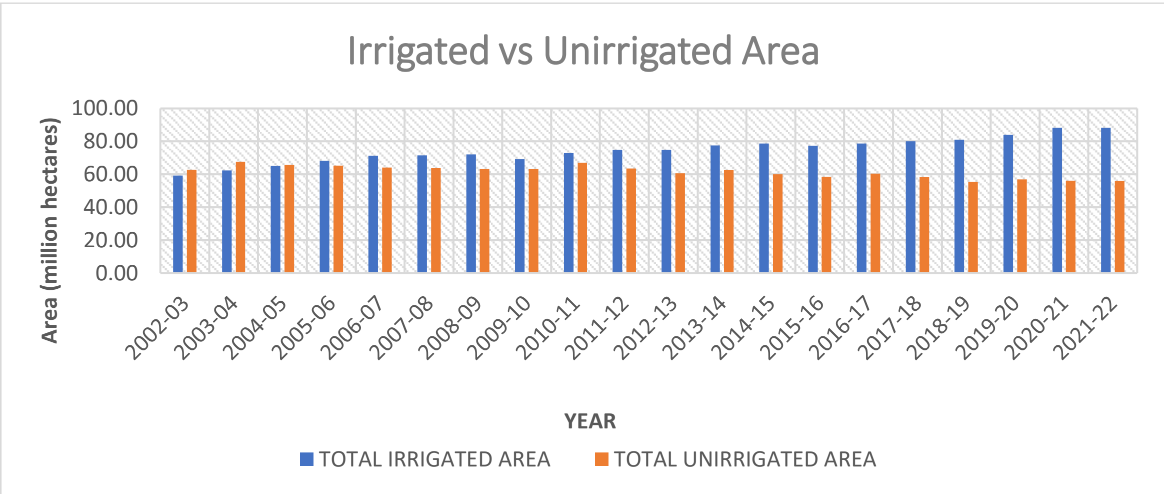
The total cropped area in India showed a generally increasing trend over the two decades, indicating expansion and intensification of agricultural land use. The area increased from a low of 122 million hectares in 2002–03 to a peak of 144.22 million hectares in 2021–22. Key contributors to this growth likely include better irrigation infrastructure, adoption of high-yielding and short-duration crop varieties, and supportive agricultural policies.



Graph 1: Total Cropped Area

6.2 Irrigated and Unirrigated Area Trends:

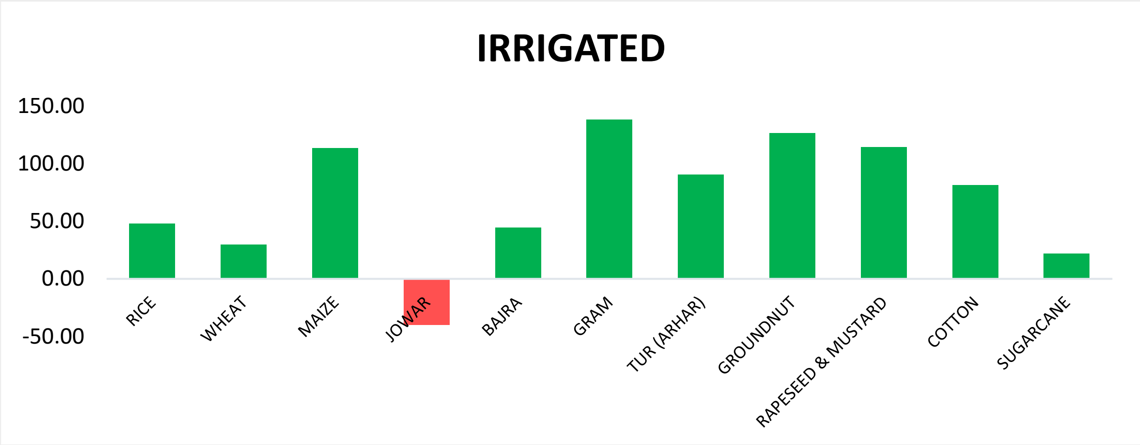
The data reflects a clear shift from rain-fed to irrigated agriculture. Irrigated areas grew consistently from 59.27 million hectares in 2002–03 to 88.25 million hectares in 2021–22. In contrast, unirrigated areas declined from 62.73 to 55.97 million hectares. The transition point where irrigated area surpassed unirrigated area occurred around 2005–06 to 2006–07, marking a critical transformation in Indian agriculture toward reliance on irrigation.



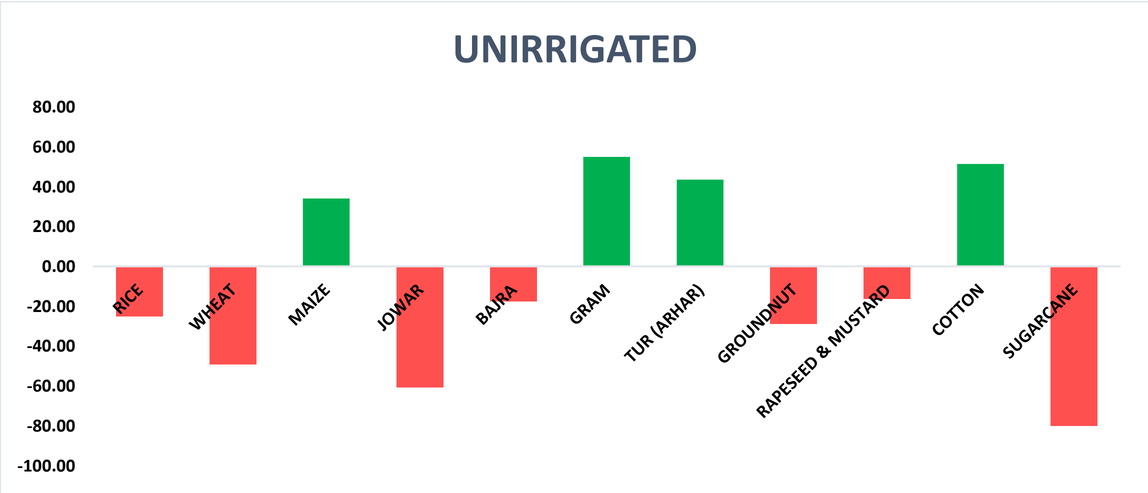
Graph 2: Irrigated and Unirrigated Area

6.3 Crop Shifts:

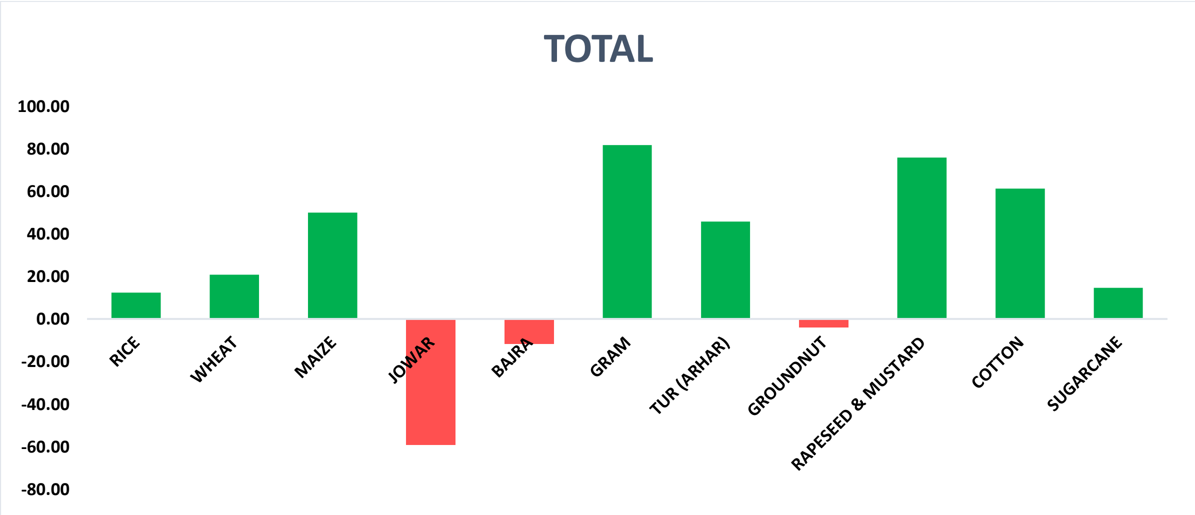
Substantial shifts were observed in the composition of irrigated and unirrigated crop areas. Crops like gram (138.21%), groundnut (126.69%), rapeseed & mustard (114.47%), and maize (113.45%) experienced significant increases in irrigated cultivation. Meanwhile, crops like rice (-25.11%), wheat (-49.17%), and sugarcane (-80.17%) saw notable reductions in unirrigated area. Jowar witnessed a major overall decline in area by -59.14%, highlighting a declining emphasis on traditional rain-fed crops. In contrast, crops such as gram, maize, and cotton recorded considerable gains in total area, reflecting a shift toward commercial and irrigation-friendly crops.



Graph 3: Crop Shifts- Irrigated Area



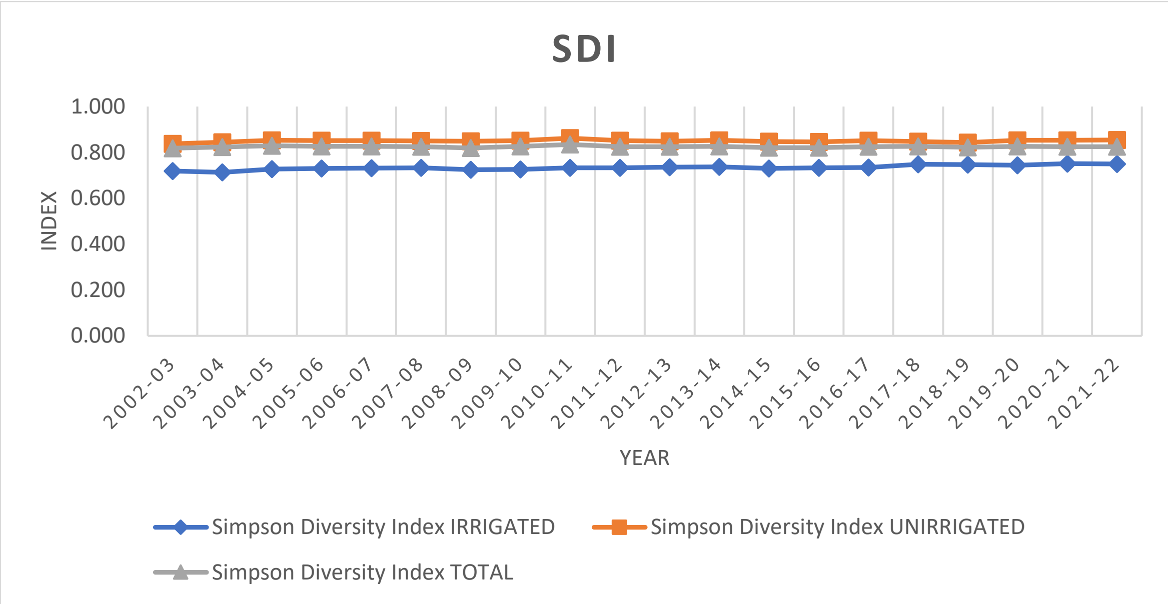
Graph 4:Crop Shifts- Unirrigated Area



Graph 5: Crop Shifts- Total Area

7. Diversification Trends

Analysis of the Simpson Diversity Index (SDI) showed that unirrigated regions consistently had higher crop diversification values (0.84–0.85) than irrigated areas (0.71–0.75), likely because rain-fed farmers rely on diversification to mitigate climate risks. However, the irrigated SDI showed a rising trend from 0.718 to 0.750 over the study period, suggesting a shift from mono-cropping (e.g., rice and wheat) to more diverse cropping under irrigation. This positive trend signals the increasing potential for sustainable and profitable diversification in irrigated areas.



Graph 6: Trends in Crop Diversity

8. Correlation Analysis:

Correlation analysis was employed to explore the relationship between irrigation intensity and crop diversification across different farming systems. This statistical approach helps identify whether variations in irrigation availability are associated with changes in diversification patterns, particularly in irrigated, unirrigated, and aggregate agricultural zones.

Statistic	Total SDI	Irrigated SDI	Unirrigated SDI
Pearson's Correlation Coefficient	-0.1007	0.908	0.1862
T-statistic	-0.42956	9.194	0.8043
Degrees of Freedom	18	18	18
P-value	0.6726	3.204×10^{-8}	0.4317
95% Confidence interval Lower	-0.5200718	0.778	-0.2793
95% Confidence interval Upper	0.3577331	0.963	0.5809

- The total Simpson Diversity Index (SDI) showed a very weak and statistically insignificant negative correlation with irrigation intensity ($r = -0.10$, $p = 0.6726$), indicating that changes in irrigation intensity had minimal impact on overall crop diversification levels.
- The irrigated SDI exhibited a strong and statistically significant positive correlation with irrigation intensity ($r = 0.908$, $p < 0.0001$). This suggests that increased irrigation is associated with greater crop diversification in irrigated areas.
- The unirrigated SDI displayed a weak, statistically insignificant positive relationship with irrigation intensity ($r = 0.186$, $p = 0.4317$), implying limited influence of irrigation changes on diversification in unirrigated zones.

9. Conclusions:

- ✓ Enhancing the adoption of micro-irrigation systems extends irrigation areas while safeguarding water resources
- ✓ Public policy should evolve towards sustainable farming methods while also focusing on household incomes while maintaining food security of the nation.
- ✓ The implementation of educational programmes should demonstrate to farmers various cropping methods alongside market data and sustainable agricultural practices.

10. Conclusion

The findings highlight a consistent expansion of agricultural land and a growing dominance of irrigation-based farming in India over the past two decades. The significant increase in irrigated areas alongside a gradual decline in rain-fed farming underscores India's agricultural transformation toward input-intensive and commercially viable farming systems. Crop shifts indicate a transition away from traditional rain-fed crops like jowar toward high-yielding, irrigation-friendly crops such as maize, gram, and cotton. While the total crop diversification (as measured by SDI) did not show a strong connection to irrigation intensity, the strong correlation within irrigated zones confirms that enhanced irrigation availability facilitates diversification in those areas. In contrast, diversification in rain-fed areas remains stagnant. These trends underline the critical role of irrigation infrastructure and policy in shaping cropping patterns and promoting diversification, which are essential for improving resilience, productivity, and income in Indian agriculture.

11. Conflict of Interest

The authors declare that they have no conflict of interest.

12. Funding Declaration

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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