Performance and Growth of Irrigation Sector in Agriculture Development in Karnataka: A Trendline Analysis

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Abstract

The research study aims at explains the performance and growth of irrigation system in agricultural development in Karnataka. It is a critical determinant of agricultural productivity, cropping intensity, crop diversification and rural economic development in Karnataka. The growth of this sector forms a backbone of Karnataka's agricultural development by reducing the vulnerability of crops to erratic monsoons, generating employment and income opportunities for farmers, improving rural livelihoods, supporting rural development, and contributing to foreign exchange earnings. The state's net irrigated area reached 46.75 lakh ha, driven primarily by a massive boom in groundwater exploitation via tubewells and borewells, which now account for nearly 80% of total irrigation as per the Economic Survey of Karnataka (2025).

The analysis of the irrigation sector in Karnataka during 2015–16 to 2024–25 reveals a clear overall improvement in irrigation coverage. Gross Irrigated Area (GIA) increased from 37.42 lakh hectares in 2015–16 to 61.20 lakh hectares in 2024–25, representing an increase of nearly 63.55 per cent. Similarly, Net Irrigated Area (NIA) increased from 32.43 lakh hectares to 49.80 lakh hectares, registering an increase of about 53.56 per cent during the study period. The trend analysis confirms that the growth in irrigated area was statistically significant. GIA recorded an annual trend coefficient of +3.371 lakh ha, with an R^2 value of 0.8247, indicating that about 82.47 per cent of the variation in GIA was explained by the time trend. The calculated t-value of 6.136 and p-value of 0.00028 indicate a highly significant positive trend. Likewise, NIA recorded an annual trend coefficient of +2.445 lakh hectares, with an R^2 value of 0.8285. Thus, about 82.85 per cent of the variation in NIA was associated with the time trend. The calculated t-value of 6.217 and p-value of 0.00025 confirm a highly significant positive trend.

Keywords: *Irrigation; Agriculture; Gross Irrigated Area; Net Irrigated Area; Trend Analysis; Karnataka; Agricultural Development.*

Introduction

Agriculture continues to be an important component of Karnataka's economy and rural livelihood system. However, agricultural production in the state is highly influenced by the variability of monsoon rainfall. Karnataka has considerable variations in rainfall, soil conditions, topography, and water availability, with many regions experiencing irregular and inadequate monsoon rainfall. Irrigation therefore plays a crucial role in reducing farmers'

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dependence on rainfall, stabilising agricultural production, increasing cropping intensity, and encouraging the cultivation of water-intensive and high-value crops.

Irrigation plays a vital role in the agricultural development and rural economy of Karnataka by improving the availability and reliability of water for crop production. Over time, irrigation development has contributed to the transformation of the agricultural economy by facilitating multiple cropping, crop diversification, higher agricultural productivity, and commercial agriculture. Irrigated areas have provided better opportunities for cultivating crops such as paddy, sugarcane, cotton, maize, horticultural crops, and other high-value agricultural commodities. In addition, irrigation development has contributed to employment generation, increased farm income, and improved rural livelihoods. Karnataka has a diverse irrigation system comprising canals, tanks, wells, tube wells, bore wells, reservoirs, and other sources. The state's irrigation infrastructure has developed through a combination of major and medium irrigation projects, minor irrigation schemes, groundwater development, tanks and canals, as well as modern micro-irrigation systems such as drip and sprinkler irrigation. Major river basins, particularly the Krishna, Cauvery, Tungabhadra, and their tributaries, have supported the development of extensive irrigation infrastructure. Important projects such as Krishna Raja Sagara, Tungabhadra, Almatti, Narayanapura, Kabini, and Hemavathi have contributed substantially to the expansion of irrigated agriculture across different regions of the state.

The state's irrigation development has expanded considerably over the long term. According to the Karnataka Economic Survey, the gross irrigated area increased substantially from earlier decades, reaching 60.64 lakh hatares in 2020–21 and 62.71 lakh hatares in 2022–23, before declining to 58.36 lakh hatares in 2023–24. These changes indicate the importance of examining not only the long-term expansion of irrigation but also the fluctuations in irrigated area associated with rainfall variability, water availability, and agricultural conditions.

In recent years, increasing pressure on water resources, recurrent droughts, climate variability, groundwater depletion, and changing rainfall patterns have created significant challenges for irrigation management in Karnataka. The state's vulnerability to rainfall variability makes efficient and sustainable water management increasingly important. In this context, micro-irrigation technologies, particularly drip and sprinkler irrigation, have emerged as important strategies for improving water-use efficiency, conserving water, and promoting sustainable agricultural development. The increasing importance of irrigation is also reflected in various government programmes and initiatives, including the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), micro-irrigation programmes, major and medium irrigation projects, minor irrigation schemes, and the modernisation of canal systems. These initiatives aim to expand irrigation coverage, improve water-use efficiency, conserve water resources, and enhance the productivity and sustainability of agriculture. Greater emphasis is also being placed on watershed development, rehabilitation of irrigation infrastructure, water conservation, and efficient utilisation of available water resources.

Research Objectives

1. The study the performance and growth of the irrigation sector in Karnataka.
2. To analyse the trends in gross cropped area, gross irrigated area and net irrigated area in the state.

Hypothesis

1. There is a significant positive trend in the irrigated area has increased in Karnataka over the past few periods.

Methodology and Data Sources

The study is based primarily on secondary data collected from various government departments, institutions, and published sources. The major sources of data include the Ministry of Agriculture and Farmers Welfare, Government of India; Land Use Statistics at a Glance; NABARD reports; the Directorate of Economics and Statistics, Government of Karnataka; Karnataka Economic Survey (2025); and the Department of Agriculture, Government of Karnataka. In addition, relevant government reports and publications, research journals, scholarly articles, newspapers, magazines, and credible websites were consulted to obtain supporting information related to irrigation and agricultural development in Karnataka.

Statistical Techniques for Data Analysis: The study employs various statistical techniques, including percentage analysis, Annual Growth Rate (AGR), Compound Annual Growth Rate (CAGR), and Linear Trend Analysis, to examine the growth and trends in Gross Cropped Area (GCA), Gross Irrigated Area (GIA), and Net Irrigated Area (NIA) in Karnataka during the period from 2015–16 to 2024–25. The collected data were systematically compiled, processed, analysed, and interpreted using Microsoft Excel, SPSS 21, EViews, and Gretl. Linear trend analysis was employed to assess the direction and magnitude of changes over time, while CAGR and AGR were used to measure the rate of growth in the selected irrigation indicators.

Compound Annual Growth Rate

$$CAGR = [(V_2/V_1)^{(1/n)} - 1] \times 100$$

Where,

V_1 is represents the value in 2015-16,

V_2 is represents the value in 2024-25

n = 10 years.

Linear Trend Analysis: The linear trend equation is:

$$Y = a + bt$$

Where,

Y = the represents the irrigation area,

a = the intercept,

b = the annual trend coefficient and

t = represents time.

Performance of Irrigation Sector in Agricultural Development in Karnataka

The study explains the performance of irrigation sector in agricultural development in Karnataka. This sector acts as the cornerstone of agricultural transformation in Karnataka, turning vulnerable rain-fed farming into a resilient, productive ecosystem. In a state where over 70% of the geographical area is semi-arid and highly vulnerable to erratic monsoons, public and private investments in water infrastructure have reshaped rural economies. The sector’s primary roles in driving agricultural improvement include:

1**) Improving Crop Productivity and Yield Stability:** Assured water access reduces dependency on the southwest monsoon. It provides a critical buffer during dry spells, stabilizing crop yields particularly in drought-prone regions like the Kalyan-Karnataka and Bayaluseeme belts.

2) Facilitating High-Value Crop Diversification: The expansion of irrigation which grew to a net area of 46.75 lakh ha has driven a massive shift away from low-yielding subsistence cereals. Agriculture farmers have transitioned to high-value commercial agriculture, including sugarcane, maize, cotton, and robust horticultural crops like pomegranates, grapes, and flowers.

3) Cropping Intensity Increasing: Reliable water supplies allow for multi-cropping systems. Farmers can cultivate a second or third crop during the rabi and summer seasons, maximizing land utility and boosting yearly farm incomes.

4) Driving Technology Adoption: The growth of localized irrigation has accelerated the uptake of modern farm inputs. Driven by state schemes like Krishi Bhagya, Karnataka has seen a surge in farm ponds and micro-irrigation technologies (drip and sprinkler systems) that optimize water-use efficiency.

Despite these achievements, structural issues remain. The growth is heavily skewed toward groundwater exploitation via tubewells, which now account for nearly 80% of total irrigation, causing severe water table depletion. Additionally, tail-end distribution gaps in major canal networks perpetuate regional disparities. For sustainable agricultural growth, Karnataka's irrigation sector is pivoting from expanding sheer infrastructure to promoting community-based micro-irrigation and strict water conservation.

Results and Discussion

Trends in the Irrigation Sector in Karnataka: A Trendline Analysis

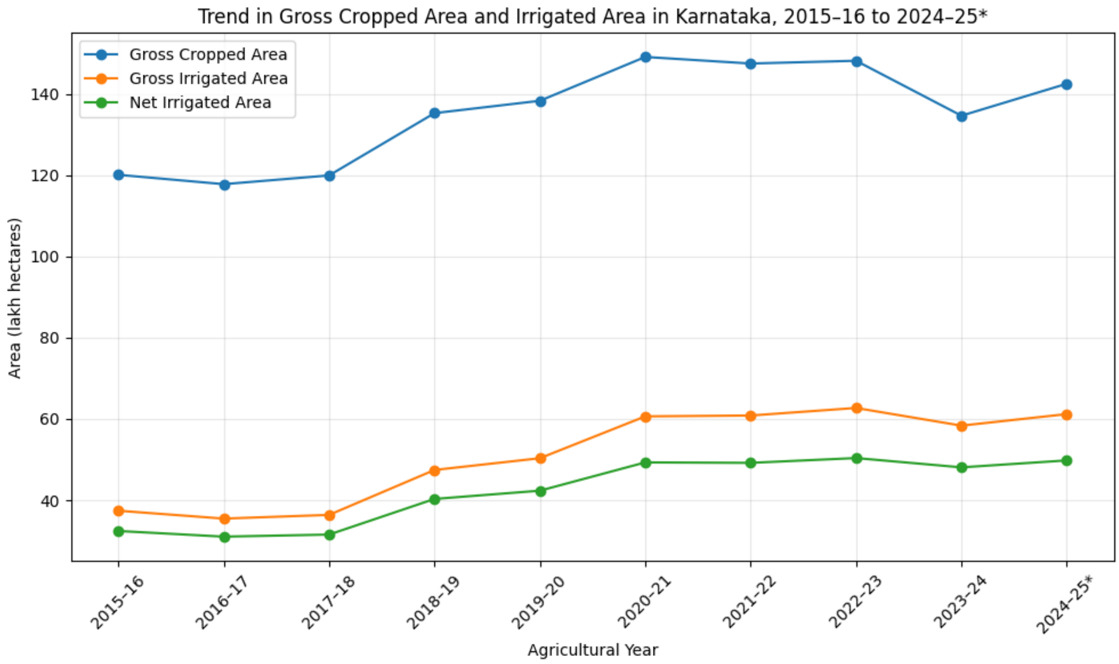
This study mainly focused on trends in gross cropped area, gross irrigated area and net irrigated area in Karnataka from 2015 to 2024.

Table-1 Trends in Irrigation and Agricultural Area in Karnataka from 2015 to 2023
(Area: In Lakh hatares)

Year	Gross Cropped Area (GCA)	Gross Irrigated Area (GIA)	Net Irrigated Area (NIA)	GIA as % of GCA
2015–16	120.09	37.42	32.43	31.2
2016–17	117.79	35.48	31.04	30.1
2017–18	119.94	36.39	31.55	30.3
2018–19	135.27	47.45	40.32	35.0
2019–20	138.31	50.34	42.35	36.4
2020–21	149.10	60.64	49.31	40.7
2021–22	147.48	60.85	49.20	41.3
2022–23	148.16	62.71	50.38	42.5
2023–24	134.64	58.36	48.09	43.4
2024–25*	142.50	61.20	49.80	42.9

Source: Government of Karnataka (2024), Karnataka Economic Survey 2024–25 and Various Report of Directorate of Economics & Statistics – 2015 to 2024.
**Note:* 2024–25 data includes compiled seasonal crop survey estimations

The above table data indicate a clear long-term expansion of irrigation in Karnataka between 2015–16 and 2024–25. Gross irrigated area increased from 37.42 lakh hatares in 2015–16 to 61.20 lakh hatares in 2024–25, representing an increase of approximately 63.5%. Similarly, net irrigated area increased from 32.43 lakh hatares to 49.80 lakh hatares, an increase of approximately 53.5% during the study period. The share of gross irrigated area in gross cropped area also increased considerably, from 31.2% in 2015–16 to 42.9% in 2024–25. This indicates that irrigation coverage expanded faster than the overall cropped area and that an increasing proportion of agricultural land was supported by irrigation. The strongest growth was observed from 2018–19 onwards. GIA increased from 47.45 lakh hatares in 2018–19 to 60.64 lakh hatares in 2020–21 and reached a peak of 62.71 lakh hatares in 2022–23. Thereafter, it declined to 58.36 lakh hatares in 2023–24 before recovering to 61.20 lakh hatares in 2024–25. These fluctuations may reflect variations in rainfall, reservoir storage, groundwater availability, and agricultural water demand.



Trendline Analysis: The linear trend model used is:

$Y = a + bt$

Where, b represents the annual trend coefficient.

Table-2 Linear Trend Results for Irrigation Sector in Karnataka

Indicator	Trend Equation*	Annual Trend Coefficient	R^2	p-value	Result
Gross Cropped Area	Y = 134.53 + 3.637X	3.637 lakh ha	0.6190	0.0119	Significant
Gross Irrigated Area	**Y = 49.96 + 3.793X**	**3.793 lakh ha/year**	**0.8434**	**0.0005**	**Highly significant**
Net Irrigated Area	**Y = 41.63 + 2.749X**	**2.749 lakh ha/year**	**0.8473**	**0.0004**	**Highly significant**

**Note:* Here, X = Year − 2019.5.

The above table-2 presents the linear trend results for the GCA, GIA, and NIA in Karnataka. The trend analysis uses the equation Y = a + bX, where X = Year − 2019.5. The annual trend coefficient indicates the average annual change in the respective indicator. The GCA shows a positive and statistically significant trend during the study period. The estimated trend equation, Y = 134.53 + 3.637X, indicates that the gross cropped area increased by approximately 3.637 lakh hatares per year. The R^2 value of 0.6190 suggests that about 61.90% of the variation in GCA is explained by the time trend. The p-value of 0.0119, which is below the 5% significance level, confirms that the observed upward trend is statistically significant.

The GIA exhibits a stronger upward trend. The trend equation Y = 49.96 + 3.793X indicates an average annual increase of approximately 3.793 lakh hatares. The R^2 value of 0.8434 shows that about 84.34% of the variation in GIA is explained by the time trend. The p-value of 0.0005 is substantially below the 1% significance level, indicating that the increasing trend in GIA is highly statistically significant. This demonstrates the considerable expansion of irrigation coverage in Karnataka during the study period. Similarly, NIA records a strong and highly significant positive trend. Its estimated equation, Y = 41.63 + 2.749X, indicates that NIA increased by about 2.749

lakh ha per year on average. The R^2 value of 0.8473 indicates that about 84.73% of the variation in NIA is associated with the time trend. The p-value of 0.0004 confirms that the trend is highly statistically significant at the 1% level.

The results clearly demonstrate that irrigation development in Karnataka has followed a statistically significant upward trajectory during the study period. Among the three indicators, GIA recorded the highest annual trend coefficient (3.793 lakh ha/year), followed by GCA (3.637 lakh ha/year) and NIA (2.749 lakh ha/year). The relatively high R^2 values for GIA and NIA (0.8434 and 0.8473, respectively) indicate a strong and consistent time-based expansion of irrigated agriculture. The statistical significance of all three trends particularly the p-values of 0.0005 for GIA and 0.0004 for NIA provides strong evidence that the observed growth is not merely due to random fluctuations. The study findings therefore suggest that the expansion of irrigation infrastructure and irrigated agricultural area has been an important component of Karnataka's agricultural development.

Growth in Irrigated Area

Between 2015–16 and 2023–24, the GIA in Karnataka increased from 37.42 lakh ha to 58.36 lakh hatares, representing an overall increase of about 55.96%. During the same period, the NIA increased from 32.43 lakh ha to 48.09 lakh ha, registering an overall growth of approximately 48.29%. The estimated CAGR was approximately 5.71% for GIA and 5.05% for NIA, indicating a steady expansion of irrigation coverage in the state during the study period.

Table –3 Growth in Irrigation Area in Karnataka (2015 to 2025)

S. No	Indicator	CAGR, 2015–16 to 2023–24
1	Gross Cropped Area	1.28%
2	**Gross Irrigated Area**	**5.06%**
3	**Net Irrigated Area**	**4.47%**

Source: Compiled Result by the Researcher

The substantially higher growth rate of irrigated area compared with GCA indicates the increasing importance of irrigation in Karnataka's agricultural system.

Hypothesis Testing

H_0: There is no significant positive trend in the irrigated area in Karnataka over the past few periods.

H_1: There is a significant positive trend in the irrigated area in Karnataka over the past few periods.

Table-4 Linear Trend and Hypothesis Testing of Irrigated Area in Karnataka

(2015 to 2024)

Indicator	Trend Equation	Annual Trend Coefficient (b)	R^2	t-value	p-value	Significance
GIA	Y = 32.541 + 3.371X	+3.371 lakh ha/ year	0.8247	6.136	0.00028	Highly significant
NIA	Y = 28.999 + 2.445X	+2.445 lakh ha/ year	0.8285	6.217	0.00025	Highly significant

Source: Compiled Result by the Researcher

The study tested the hypothesis that there is a significant positive trend in the irrigated area of Karnataka during the period 2015–16 to 2024–25. Linear trend regression was applied separately to GIA and NIA. The results reveal a strong and statistically significant upward trend in both indicators. The trend equation for GIA was estimated as Y = 32.541 + 3.371X, with an annual trend coefficient of 3.371 lakh hatares. The R^2 value of 0.8247 indicates that

82.47 per cent of the variation in GIA is explained by the time trend. The calculated t-value of 6.136 and p-value of 0.00028 demonstrate that the trend is statistically significant at the 1 per cent level.

Similarly, the trend equation for NIA was $Y = 28.999 + 2.445X$, indicating an annual increase of about 2.445 lakh ha. The R^2 value of 0.8285 indicates that 82.85% of the variation in NIA is explained by the time trend. The calculated t-value of 6.217 and p-value of 0.00025 confirm that the positive trend is statistically significant at the 1 per cent level. Since the p-values for both GIA and NIA are less than 0.01, the null hypothesis is rejected and the alternative hypothesis is accepted. Thus, the study establishes that there has been a significant positive trend in the irrigated area of Karnataka during 2015–16 to 2024–25. The findings indicate that the expansion of irrigation has strengthened the agricultural development potential of the state by improving water availability, supporting multiple cropping, reducing dependence on rainfall and facilitating agricultural intensification and diversification.

Conclusion

The study concludes that the irrigation sector has played an increasingly important role in agricultural development in Karnataka during 2015–16 to 2024–25. Both GIA and NIA recorded substantial growth over the study period, demonstrating the expansion of irrigation facilities and increasing access to assured water for agricultural activities. The trendline analysis provides strong statistical evidence of this improvement. GIA increased at an estimated rate of 3.371 lakh ha per year, while Net Irrigated Area increased at 2.445 lakh ha per year. The high R^2 values of 0.8247 and 0.8285, respectively, demonstrate a strong positive relationship between time and irrigated area. The very low p-values further confirm that these trends are statistically significant. Therefore, the study rejects null hypothesis and accepts the alternative hypothesis, confirming that there has been a significant positive trend in the irrigated area of Karnataka. The expansion of irrigation has contributed to agricultural stability, increased cropping opportunities, improved crop diversification and reduced dependence on uncertain rainfall.

However, the future development of the irrigation sector should focus not merely on expanding irrigated area but also on efficient and sustainable water management. Greater emphasis should be placed on drip and sprinkler irrigation, groundwater recharge, tank rejuvenation, modernization of canal systems, watershed development and the adoption of climate-resilient agricultural practices. Sustainable management of groundwater is particularly important because of the increasing dependence on bore wells and tube wells. Finally, the findings suggest that continued investment in efficient, equitable and climate-resilient irrigation infrastructure will be essential for achieving sustainable agricultural growth and improving the livelihoods of farming communities in Karnataka.

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