Mysore J. Agric. Sci., 59 (2) : 57-67 (2025)

Impact of Automated Canal Irrigation System on Farmers' Income in Narayanpur Left Bank Canal Command Area of Upper Krishna Project

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Received : October 2024
Accepted : December 2024

ABSTRACT

The present study attempts to analyse the impact of automated canal irrigation system on farmers' income in Narayanpur Left Bank Canal command Area of Upper Krishna Project. A purposive random sampling procedure was used to select a representative and homogeneous group of 120 paddy-cultivating farmers from the NLBC command area. These farmers were sampled from both the pre-automation and post-automation periods to ensure consistency in data collection across both time frames. To study the impact of automated canal irrigation system on farmers' income, the widely used approaches of cross-comparison and Difference-in-Difference (DID) techniques were employed. The results showed that selected indicators had positive effects on farmers' income during post-automation period of canal irrigation. Specifically, improvements were observed in the area under paddy cultivation, yield, gross value of production (GVP) of the paddy crop and cropping intensity compared to pre-automation period. The Cobb-Douglas type revenue function was found to be appropriate specification and explained the sufficient variations in the GVP. The co-efficient of interaction indicated significant and positive impact of automated irrigation system on the respondents' income. Whereas the results of Data Envelopment Analysis (DEA) showed that the majority of the farmers adopting canal irrigation falls under higher efficiency classes compared to non-adopters. Thus, research advocates the replication of the similar reforms at other places which would greatly help in boosting farmers' earnings through increased crop production and improved irrigation water use efficiency.

Keywords : Automated canal irrigation, Cross - comparison, Difference-in-Difference, Impact, Income

IRRIGATION has long been acting as a cornerstone of increased agricultural productivity in India, a country where agriculture contributes significantly to both employment and economic output. However, Indian agriculture remains heavily dependent on the highly variable and erratic monsoon. With an average annual rainfall of approximately 1200 mm, nearly 75 per cent of the country's total precipitation is concentrated during the four-month southwest monsoon season from June to September. This irregular distribution leads to both seasonal water shortages and regional disparities in water availability, making irrigation essential to ensuring crop growth, particularly in arid and semi-arid regions. In fact, more than 30 per cent of India's net sown area receives less than 750 mm of rainfall annually, while another 43 per cent receives between 750 mm and 1150 mm, underscoring the critical role that irrigation plays in stabilizing agricultural output (Butt *et al*., 2021).

Canal irrigation systems have historically been a key component of India's agricultural infrastructure, enabling farmers to access reliable water supplies even in areas prone to rainfall shortages. However, many of these systems, including the Narayanpur Left Bank Canal (NLBC) Command Area of the Upper Krishna Project (UKP) in Karnataka, face significant challenges related to water management. Traditional canal systems are often plagued by inefficiencies such as water wastage, inequitable water distribution, and mismanagement leading to suboptimal agricultural performance and reduced farmer satisfaction. These inefficiencies are particularly pronounced in large-scale irrigation projects, where farmers located at the head reaches of canals often receive more than their fair share of water, while those further downstream suffer from shortages (Mane *et al*., 2021 and Sakib, 2024).

Recognizing these challenges, the introduction of automated canal irrigation systems marks a pivotal shift in the management and distribution of water resources. Automation seeks to improve the efficiency of irrigation by ensuring that water is distributed evenly across the canal network, minimizing wastage, and improving the timeliness of water delivery to farmers. These advancements are especially crucial in regions like the NLBC command area, where paddy is a major crop. In this context, automated irrigation has the potential to significantly enhance water use efficiency, increase crop yields and consequently improve farmer incomes (Arunkumar and Ambujam, 2010).

Furthermore, the underutilization of canal systems is a global concern, with many large-scale irrigation projects failing to meet their expected potential. Studies have shown that issues such as water logging, salinity and poor infrastructure contribute to low efficiency in canal systems, diminishing the returns on investment in irrigation projects. The automation of the NLBC system offers a solution to many of these issues, with the potential to reduce inefficiencies and improve water distribution. By ensuring that all farmers in the command area receive their fair share of water, regardless of their position in the canal system, automation can help boost agricultural productivity and enhance the livelihoods of farmers. Additionally, the efficient management of water resources is increasingly critical in the face of climate change, which is expected to exacerbate the variability of rainfall patterns in the coming decades.

With this background, the present study examines the impact of automated canal irrigation system on farmers' incomes in the NLBC command area. This study focuses on key indicators like farm income, cropping intensity and water use efficiency, providing insights into how automation can boost agricultural productivity and contribute to food security.

Methodology

Study Area

The study was carried out in Narayanpur Left Bank Canal (NLBC) command area which is the longest main canal among six branches of Upper Krishna Project of Karnataka State (Table 1).

Table 1

Branches of Upper Krishna Project (Length in km)

Particulars	Length of Main Canal	Length of Distributaries	Length of Laterals
Narayanpur Left Bank Canal	77.50	240.00	450.00
Hunasagi Branch Canal	11.50	80.00	250.00
Shahapur Branch Canal	76.00	375.00	752.00
Indi Branch Canal	64.00	173.00	280.00
Jewargi Branch Canal	40.00	41.00	127.00
Mudbal Branch Canal	50.00	170.00	220.00
Total	319.00	1079.00	2079.00

Sampling Technique and Sample Size

The study employed a purposive random sampling method to ensure the selection of a representative and homogeneous group of farmers from the NLBC Command Area. The automation was implemented in NLBC command area during 2022, A total of 120 paddy farmers were selected, split evenly between the pre-automation (60 farmers) and post-automation (60 farmers) periods. These farmers were further categorized into adopters (30) and non-adopters (30) within each period to provide a balanced comparison between the groups.

Nature and Data Sources

Data required to achieve the objectives of the study were collected from both primary and secondary sources:

The primary data were gathered using survey methods and pre-tested schedules to elicit first-hand insights from farmers regarding cultivation practices, input use patter, crop yield, income and water usage patterns.

The required secondary data were acquired from various departmental publications, including those from organizations such as Command Area Development Authority, Raitha Samparka Kendra, Directorate of Economics and Statistics and Krishna Bhagya Jala Nigam Limited to cross-validate and strengthen the analysis.

Analytical Tools

The study employed a combination of quantitative analytical tools to assess the impact of the automated canal irrigation system on farmers' incomes and productivity as detailed below.

Difference in Differences Technique

The Difference in Differences (DID) technique is a statistical method used to estimate the impact of a reform, program or technological change by comparing the differences in outcomes between a treatment group (in this case, farmers using the automated canal irrigation system) and a control group (non-adopters). The model is represented as an interaction between time and treatment group dummy variables.

$$Yi = \beta_0 + \beta_1*[D_A] + \beta_2*[D_T] + \beta_3*[D_A D_T] + U_i$$

$$Yi=\beta_0+ \beta_1 T+\beta_2 t+ \beta_3 T_t+\ldots + U_i \quad ....(1)$$

Where,

Yi is GVP of Paddy

D_A is a automation dummy (A=1 if the individual is in the automation group and A=0 if farmer is in the control group) D_T is time dummy (T=1 in the post-automation period and t = 0 in the pre- automation period)

$D_A D_T$ will be the estimate of the actual impact of automation.

Cross Comparison Principle

The study employs a cross-comparison of various indicators used to evaluate the impact of the automated canal irrigation system on the NLBC Command Area. The indicators are grouped into five key categories: productivity, socio-economic, sustainability, equity, and water availability. These indicators assess different aspects, including cropping intensity, farm income and cost of production, water charges collection and water distribution performance (Kloezen *et al*., 2015 and Hussain, 2016). These indicator categories are presented in Table 2.

TABLE 2

Category of Indicators used for Cross Comparison

Indicator's category	Indicators
Productivity indicators	Cropping intensity, Productivity and gross value product (GVP) of Paddy
Socio-economic indicators	Cost of production of major crops, irrigation cost and income of the farmers
Sustainability indicators	Operations and Maintenance expenditure, water charges collection and gross margin to cost of production ratio
Equity indicator	Delivery performance ratio
Water availability	Increase in water quantity available to farmers

Data Envelopment Analysis

DEA was applied by using both classic models constant returns to scale (CRS) and variable returns to scale (VRS) with input orientation, in which one seeks input minimization to obtain a particular product level. Under assumption of CRS and VRS, the linear programming models for measuring the efficiency of farmers (Coelli *et al*., 1998) can be specified as under.

$$\text{Min } \theta\ \lambda\ \theta$$

$$\text{Subject to} \quad yi + Y\lambda \geq 0 \qquad \theta Xi - X\lambda \geq 0$$

$$\lambda \geq 0 \quad ....(2)$$

Where,

y_i is a vector of output of the ith TPF Farmers

x_i is a vector of inputs of the ith TPF Farmers

Y is an output matrix (n x m) for n TPF Farmers

X is an input matrix (n x k) for n TPF Farmers

θ is the efficiency score, a scalar whose value will be the efficiency measure for the i^{th} TPF farmers. If θ = 1, Total productivity factor (TPF) will be efficient; otherwise, it will be inefficient.

λ is a vector (*nx1*) whose values are calculated to obtain the optimum solution. For an inefficient TPF, the λ values will be the weights used in the linear combination of other efficient TPFs, which influence the projection of the inefficient TPF on the calculated frontier.

The specification of constant returns is only suitable when the firms are working at optimum scale. Otherwise, measures of technical efficiency can be mistaken for scale efficiency, which considers all types of returns to production, *i.e.,* increasing, constant and decreasing. Therefore, the CRS model is reformulated by imposing a convexity constraint. The measure of technical efficiency obtained in the model with variable returns is also named pure technical efficiency as it is free of scale effects and the following linear programming model estimates it:

$$\text{Min } \theta\ \lambda\ \theta$$

$$\text{Subject to} \quad - yi + Y\lambda \geq 0$$

$$\theta Xi - X\lambda \geq 0$$

$$N1\lambda = 1$$

$$\lambda \geq 0 \quad ....(3)$$

Where,

N1 is a vector (*n x1*) of ones.

When there are differences between the values of the efficiency scores in the models CRS and VRS, scale inefficiency is confirmed, indicating that the return to scale is variable, *i.e.,* it can be increasing or decreasing. The scale efficiency values for each analyzed unit can be obtained by the ratio between the scores for technical efficiency with constant and variable returns as follows.

$$\theta s = \theta CRS\ (XK,YK)/\theta VRS\ (XK,YK) \quad ....(4)$$

Where,

$\theta CRS\ (XK,YK)$ is the technical efficiency for the model with constant returns

$\theta VRS\ (XK,YK)$ is the technical efficiency for the model with variable returns

θs is scale efficiency

It was pointed out that model makes no distinction as to whether TPF is operating in the range of increasing or decreasing returns (Coelli *et al.* 1998). The only information that one has is that if the value obtained by calculating the scale efficiency is equal to one, the TPF will be operating with constant returns to scale. However, when θs is smaller than one, increasing or decreasing returns can occur. Therefore, to understand the nature of scale inefficiency, it is necessary to consider another problem of linear programming *i.e.,* the convexity constraint of model, $N1\lambda=1$, is replaced by $N1\lambda \leq 1$ for the case of non-increasing returns, or by $N1\lambda \geq 1$, for the model with non-decreasing returns. Therefore, in this work the following models were also used for measuring the nature of efficiency.

Non-increasing returns

$$\text{Min } \theta\ \lambda\ \theta$$

Subject to $- yi + Y\lambda \geq 0$

$$\theta Xi - X\lambda \geq 0$$

$$N1\lambda = 1$$

$$\lambda \geq 0 \quad ....(5)$$

Non-decreasing returns

$$\text{Min } \theta\ \lambda\ \theta$$

Subject to $- yi + Y\lambda \geq 0$

$$\theta Xi - X\lambda \geq 0$$

$$N1\lambda = 1$$

$$\lambda \geq 0 \quad ....(6)$$

Results and Discussion

Socio-economic Characteristics of Sample Respondents in the Study Area

Information presented in Table 3 on the socio-economic characteristics of sample respondents indicate that the majority of respondents from both adopter and non-adopter groups fell in the middle age category of 31-50 years, with 70 per cent of adopters and 66.67 per cent of non-adopters. Thus, middle-aged farmers were more active in adopters of the canal irrigation system. Farmers below 30 years were fewer, representing only 20 per cent of adopters and 100 per cent of non-adopters. Meanwhile, farmers above 51 years were more common among non-adopters (23.33%) than adopters (10.00%). The results indicated that younger and middle-aged farmers are more inclined towards adopting new irrigation technologies, likely due to their willingness to try for innovative things and experiment the improved methods in farming.

The education levels of the respondents revealed interesting trends. Relatively higher percentage of adopters were found in the higher education category (PUC and above), where 16.67 per cent of adopters had pursued pre-university or higher education, compared to only ten per cent in the case of non-adopters. On the other hand, non-adopters had a higher percentage of primary-level education (50%) compared to adopters (40%). These results suggest that education plays an important role in the decision to adopt canal irrigation systems, with more educated farmers showing a higher likelihood of adoption.

The information on family structure between the two groups revealed a clear distinction. A significantly higher percentage of non-adopters belonged to nuclear families (83.33%) compared to adopters (70%). Conversely, joint families made up 30 per cent in the case of adopters and only 16.67 per cent in the case of non-adopters. Thus, implied that joint families, with a larger pool of resources and labor, are more likely to adopt new systems like canal irrigation, possibly due to greater collective decision-making and risk-sharing capabilities.

Landholding size is another important factor influencing the adoption of irrigation systems. The majority of respondents in both groups were small farmers, with 46.67 per cent of adopters and 43.33 per cent of non-adopters owning less than 5 acres. Medium-sized farms (5-10 acres) also formed a significant proportion, with 36.67 per cent of adopters and 43.33 per cent of non-adopters falling into this category. Interestingly, large farmers (>10 acres) constituted for relatively smaller proportion of 16.67 per cent and 13.33 per cent in the case of adopters and non-adopters, respectively. Thus, adoption of canal irrigation systems is not limited to larger landholders but is independent of landholding size. The average landholding size was slightly higher for adopters (6.53 acres) compared to non-adopters (6.40 acres), indicating that larger landholding could provide better opportunities for investing in irrigation systems. Household income appears to be another determining factor. Relatively higher proportion of both adopters (53.33%) and non-adopters (50%) had annual incomes up to Rs.2 lakh. While, proportion of adopters (40%) in the income category between Rs.2 lakh and Rs.6 lakh was slightly lower than those non-adopters (43.33%).

Farmers with household incomes above Rs.6 lakh were evenly distributed, with 6.67 per cent of respondents in both groups. These facts suggested that while household income is relevant, it is not a decisive factor in distinguishing adopters from non-adopters of canal irrigation systems, as the income distribution is relatively similar across both categories.

The results on significant socio-economic factors influencing the adoption of canal irrigation systems indicated that age, education level, family type and landholding size were key characteristics that differentiate adopters from non-adopters. Younger and more educated farmers, particularly from joint families, are more inclined toward adopting irrigation systems, which can be attributed to their higher risk tolerance, access to collective resources and potential for innovation. However, household income did exerted a major role in adoption decisions, as income distributions were similar across both groups. These insights can guide policymakers and extension services in targeting specific farmer groups for the promotion and adoption of irrigation technologies, ultimately contributing to enhanced agricultural productivity and farmer welfare.

Impact of Automated Canal Irrigation on Farmers' Income

The results on DID model used to evaluate the impact of the automated canal irrigation system on farmers'

TABLE 3
Socio-economic characteristics of sample respondents in the study area

		Particulars	Adopters		Non-Adopters		Overall	
I		Age group (No.)						
	a	Below 30 years	6	(20.00)	3	(10.00)	9	(15.00)
	b	Between 31-50 years	21	(70.00)	20	(66.67)	41	(68.33)
	c	Above 51 years	3	(10.00)	7	(23.33)	10	(16.66)
		Total	30		30		60	
II		Education Level						
	a	No formal education	4	(13.33)	3	(10.00)	7	(11.66)
	b	Primary	12	(40.00)	15	(50.00)	27	(45.00)
	c	High school	9	(30.00)	9	(30.00)	18	(30.00)
	d	PUC and above	5	(16.67)	3	(10.00)	8	(13.33)
III		Type of family						
	a	Joint	9	(30.00)	5	(16.67)	14	(23.33)
	b	Nuclear	21	(70.00)	25	(83.33)	46	(76.66)
IV		Land holding (No.)						
	a	Small farmers (<5 acres)	14	(46.67)	13	(43.33)	27	(45.00)
	b	Medium farmers (5-10 acres)	11	(36.67)	13	(43.33)	24	(40.00)
	c	Large farmers (>10 acres)	5	(16.67)	4	(13.33)	9	(15.00)
		Avg. Land Holding (in acres)	6.53		6.40		6.78	
VI		Household income (Rs.)						
	a	Upto 2 lakhs	16	(53.33)	15	(50.00)	31	(51.67)
	b	2 lakhs to 6 lakhs	12	(40.00)	13	(43.33)	25	(41.66)
	c	Above 6 lakhs	2	(6.67)	2	(6.67)	4	(6.67)

Note : Figures in parentheses indicate per cent to the respective totals income in the NLBC Command Area of the Upper Krishna Project (UKP) revealed several key findings (Table. 4). The intercept term, which represents the base level of income in the absence of other influencing factors, is positive and highly significant ($p < 0.01$), with a coefficient of 5.188. This suggested that, holding all other factors influencing constant, the initial income level of farmers is quite substantial. Among the socio-economic variables, the number of years of schooling showed small but positive coefficient (0.019), but it is not statistically significant. This indicates that the level of education does not have a strong or meaningful effect on farmers' income in the context of this study. Similarly, farming experience, with a coefficient of 0.007, shows a positive but non-significant influence on income. This implies that, although experience contributes positively, it is not a major factor in determining income levels in this case. As income is going to be affected by many factors that are influencing the farm production and price realisation, etc.

In contrast, the cultivated area showed substantial positive impact on income, with a highly significant coefficient of 1.263 ($p < 0.01$). This finding suggests that farm size is a crucial determinant of income, with larger farms yielding significantly higher returns. This result is consistent with the expectation that farmers with more land have greater production capacity and consequently, higher income potential, due to realization of benefits of economies of scale. However, input costs such as expenditure on seeds and fertilisers showed negative impact but coefficients were non-significant. The coefficient for seeds is -0.125, while that for fertilisers is -0.100, indicating that higher expenditure on these inputs does not significantly improve income and may even reduce it slightly, though the effects are statistically insignificant. On the other hand, expenditure on plant protection chemicals (PPC) exhibited a positive and significant relationship with income (0.110, $p < 0.05$). This fact suggested that the use of PPC has a meaningful and positive effect on agricultural productivity and consequently, on income by

TABLE 4

Estimated Parameters of Regression from DID Model

Explanatory variables	Parameters	Co-efficients	Standard Error
Intercept	a	5.188 ***	0.128
Schooling (Yrs.)	X_1	0.019	0.017
Farming Experience (Yrs.)	X_2	0.007	0.010
Area (acre)	X_3	1.263 ***	0.237
Seeds (Rs.)	X_4	- 0.125	0.149
Fertiliser (Rs.)	X_5	-0.100	0.136
PPC (Rs.)	X_6	0.110 **	0.056
Machine labour (Rs.)	X_7	0.163	0.117
Human labour (Rs.)	X_8	-0.252	0.213
Irrigation cost (Rs.)	X_9	0.293	0.244
Automation	D_A	1.301 ***	0.295
Time period	D_T	0.168 ***	0.046
Interaction	D_AD_T	0.236 **	0.117
Coefficient of determination	R^2	0.947	
Adjusted R^2	Adj. R^2	0.934	
No. of observations	N	120	

Note : ***, ** and * indicate significant at one per cent, five per cent and ten per cent level of probability, respectively.

controlling the pest and diseases. For labour costs, machine labour has a positive effect on income (coefficient = 0.163), while human labour showed a negative effect (coefficient = -0.252), however the coefficients for both the variables were statistically non-significant. Irrigation costs exhibited a positive but non-significant impact on income, with a coefficient of 0.293, suggesting that, while irrigation is important, its cost does not have a strong direct effect on income levels. The results were on par with the study conducted by Sagar and Gaddi (2021) while studying economic impact of UAS-B released sugarcane variety (VCF 0517) in Southern Dry Zone of Karnataka.

The key dummy variables of interest, the automation of the canal irrigation system (D_A), showed a highly significant positive coefficient of 1.301 ($p < 0.01$). This indicated that the implementation of the automated system has a strong and beneficial impact on farmers' income, likely due to improved water management and increased agricultural productivity. Additionally, the coefficient for the time period (D_T) was positive and significant (0.168, $p < 0.01$), indicating that income levels improved over time, independent of automation. The interaction term (D_AD_T), which captures the combined effect of automation and time, was also positive and significant (0.236, $p < 0.05$). Thus, the impact of automation system on income grows stronger over time, highlighting the cumulative benefits of automation on farmers' income in the long run. The model demonstrated a high explanatory power, with an R^2 of 0.947 and an adjusted R^2 of 0.934, indicating that the independent variables explained approximately 95 per cent of the variation in farmers' income. The results were in line with the study conducted by Sudha *et al.,* (2006) while studying economic impact of commercial hybrid seed production of tomato and okra vegetables on farm income, employment and farm welfare in Karnataka.

Comparative Analysis of Performance Indicators

The adoption of the automated canal irrigation system in the NLBC command area of the Upper Krishna Project has significantly enhanced key performance indicators for paddy cultivation. A comparative analysis between the pre-automation and post-automation periods revealed notable improvements in cultivated area, yield, cost of production, cropping intensity and profitability, which are presented in Table-5.

The average area under paddy cultivation expanded by 33.50 per cent, increasing from 2.15 acres during pre-automation to 2.87 acres during post-automation period. This increase was primarily attributable to the more efficient and reliable water distribution provided by the automated system. As water became more accessible, farmers were able to bring additional land under cultivation, particularly in areas previously affected by water scarcity. A substantial improvement was observed in paddy yield levels too, which showed an increase of 34.80 per cent from 2149.75 kg per acre to 2898.15 kg per acre. The timely and consistent irrigation enabled by the automated system likely contributed to better crop growth and reduced water stress, resulting in higher yields. The availability

Table 5

Comparison of Selected Performance Indicators

Indicators	Pre-Automation period	Post-Automation period	Per cent change
Area under paddy crop (acre)	2.15	2.87	33.50
Paddy yield (Kg./acre)	2149.75	2898.15	34.80
Cost of production (Rs./q)	1468.50	1739.25	18.50
Cropping intensity (%)	145.02	195.10	34.50
Returns per rupee of expenditure	1.21	1.40	15.70

of adequate water throughout the growing season is a critical factor in achieving such productivity gains. The results were in line with the study entitled comparison of cost and returns of major food crops under Central Dry Zone of Karnataka conducted by Hamsa *et al.* (2017).

However, there was a corresponding increase in the cost of production, which showed an increase of 18.50 per cent from Rs.1468.50 per quintal to Rs.1739.25 per quintal. This increase may be attributed to higher input costs, such as fertilizers and labor, associated with managing a larger cultivated area. Additionally, the operational or additional cost of maintenance of the automated system could have contributed to this rise. The cropping intensity also increased significantly by 34.50 per cent, from 145.02 per cent to 195.10 per cent. Thus, farmers could able to cultivate more crops per year due to better and assured water availability, leading to more efficient land use. Finally, the returns per rupee of expenditure showed an increase of 15.70 per cent, from 1.21 to 1.40. Despite higher production costs, increased yields and cropping intensity led to higher profitability, demonstrating the financial viability of the automated irrigation system.

Comparative Technical Efficiency of Paddy Farming

Information presented in Table 6, unveils the results on technical efficiency in paddy farming. It could be observed that there existed significant differences in technical efficiency levels between adopters and non-adopters of the automated canal irrigation system in the study area. The farmers were categorized into efficiency classes under both the CRS and VRS.

In the efficiency class of less than 50 per cent, no adopters fall into this category, indicating that all farmers utilizing the automated system operate above this threshold. Conversely, six farmers (10%) exhibited technical efficiency below 50 per cent under non-adopters under CRS and one farmer (1.67%) achieved this level under VRS conditions. This highlights the initial advantage that adopters have in terms of operational efficiency. In the 50-79 per cent efficiency class, a mixed scenario was observed, wherein 26 farmers of adopter category (43.33%) under CRS and14 (23.33%) farmers under VRS operating at this efficiency category. For non-adopter category, 28 farmers (46.66%) under CRS and 26 (43.33%) under VRS achieved this level of efficiency. These results suggested that both groups have a considerable number of farmers in high technical efficiency range, however, the proportion was higher in the adopters category than non-adopters. The scenario is also with respect to overall efficiency. Similar results were reported by Ajayakumar *et al.,* (2023) in their study titled resource use efficiency of pigeonpea farming in Kalyana-Karnataka region.

The most promising results were found with respect to the efficiency class of efficiency above 79 per cent. More than fifty per cent under CRS (56.66%) and VRS (76.67%) under adopter

TABLE 6

Comparison of Technical Efficiency of Paddy Farming in the Study Area

Efficiency class	Adopters		Non-Adopters	
	CRS	VRS	CRS	VRS
<50 %	-	-	6 (10.00)	1 (1.67)
50-79 %	26 (43.33)	14 (23.33)	28 (46.66)	26 (43.33)
Ã 79%	34 (56.66)	46 (76.67)	26 (43.33)	33 (55.00)
Mean Index	0.829	0.912	0.764	0.843

Note : CRS = Technical efficiency under Constant Returns to Scale and
VRS = Technical efficiency under Variable Returns to Scale

category were achieved this very high efficiency level, while in the case of non-adopters, 43.33 per cent under CRS and 55 per cent under VRS efficiency belonged to this high efficiency category. Thus, a significant portion of adopters operates at a high level of technical efficiency, reinforcing the benefits of the automated system. The mean efficiency index further illustrates these differences. Adopters have a mean index of 0.829 under CRS and 0.912 under VRS, compared to respective indices of 0.764 and 0.843 for non-adopters. This data underscores the advantages of adopting automated irrigation technology, suggesting that it leads to better resource utilization and higher technical efficiency among farmers. Hence, the automated canal irrigation system played a crucial role in enhancing technical efficiency on farms involved in paddy cultivation. The results were in line with the study entitled economics and resource use efficiency of little millet cultivation in central dry zone of Karnataka by Amrutha and Chandrakanth (2018).

The automated canal irrigation system in the NLBC command area has shown a significant positive impact, increasing agricultural productivity by 34 per cent and farmers' income by 15 per cent. Additionally, the system has expanded the area under irrigation and boosted cropping intensity, enhancing the efficiency of water use. These improvements underscore the role of modern irrigation technologies in driving sustainable agricultural growth, improving livelihoods and optimizing resource management. Thus, the findings of the present research advocates that replicating similar reforms in other regions would greatly help boost farmers' earnings through increased crop production, higher GVP and improved irrigation water-use efficiency.

Acknowledgement : The author gratefully acknowledges the support received through the Doctoral Fellowship from the Indian Council of Social Science Research (ICSSR), Ministry of Education, Government of India.

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