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Economic assessment of paddy production under canal and tube well irrigation systems in Raipur district of Chhattisgarh

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Abstract

The present study conducts a comparative assessment of paddy cultivation under canal and tube well irrigation systems in selected villages of Raipur district of Chhattisgarh. Primary data was gathered from 115 households under canal and tube well irrigation through purposive random sampling and used requisite analytical tools. The results reveal that highest cost was incurred under tube well irrigation (Rs 60754.35/ha) than canal irrigation (Rs 55575.08/ha). Gross returns was found to be Rs 172659.83/ha and Rs 152327.42/ha under tube well irrigation and canal irrigation respectively.

Keywords: Cost of cultivation of paddy, canal irrigation, tube well irrigation, resource use efficiency, water use efficiency.

Introduction

Rice (*Oryza sativa* L.) is one of the most important food crops in Asia, while its production is strongly dependent on adequate water availability, particularly in irrigated lowland systems. At the same time, increasing competition for irrigation water has made improving water productivity and producing more rice with less water an important challenge for sustainable rice production (Bouman & Tuong, 2001) ^[2]. With the growing global population, increasing climate variability, agricultural intensification, and rising competition for water resources, greater investment in agriculture has become essential. Expanding and improving irrigation facilities is therefore necessary to ensure a reliable water supply and sustain agricultural production (Deepak & Choudhary VK, 2025) ^[3].

Irrigation source is an important component of agricultural water management because the availability, timing and cost of water influence crop productivity and resource utilization. In South Asian rice-based systems, both canal irrigation and groundwater irrigation have played major roles. Groundwater had become an important irrigation source, either independently or in combination with surface water (Erenstein, 2009) ^[4]. The increasing dependence on groundwater, however, raises concerns regarding long-term resource sustainability). Declining groundwater levels in the Trans Indo Gangetic Plain and emphasized artificial recharge and improved land and water management as important measures for groundwater conservation (Ambast *et al.*, 2006) ^[1]. Groundwater depletion in India is closely linked with the interaction of agricultural, energy and food policies and therefore requires a broader water–energy–food nexus approach (Mukherji, 2022) ^[8].

Water use efficiency has consequently become an important dimension of sustainable rice production. Alternate wetting and drying can reduce water inputs substantially while maintaining comparable or improved rice yields under appropriate conditions (Ishfaq *et al.*, 2020) ^[5]. At the farm level, differences in technical efficiency and constraints were found among rice farms using canal, well and tank irrigation highlighting the importance of timely irrigation and efficient use of production resources (Balamurugan *et al.*, 2018). Similarly, in Chhattisgarh, differences in resource use efficiency among paddy growing farm households were observed and emphasized efficient allocation of seed, labour, machinery, fertilizer and plant-protection inputs (Singh *et al.*, 2023) ^[10].

Particular relevance has been seen in cost, returns and resource use efficiency of rice under assured, protective and rainfed condition in the Gangrel dam command area in the mid plains of Chhattisgarh and emphasized location specific irrigation scheduling for sustainable water resource management (Deepak *et al.*, 2025) ^[3]. The efficient management of irrigation water requires not only adequate water availability but also matching irrigation supply with the actual water requirement of the crop. Crop water requirement varies according to weather conditions, crop characteristics, soil properties and crop growth stages. Therefore, location specific estimation of crop water requirements is important for improving irrigation scheduling and water use efficiency (Nath *et al.*, 2022) ^[9]. Research on rice has also shown that irrigation volume, rainfall and irrigation management practices significantly influence irrigation water productivity (Monaco & Sali, 2018) ^[7].

Objectives

1. To assess the economic analysis and resource use and water use efficiency of paddy production in the study area.
2. To identify major constraints and suggestions for improving irrigation efficiency and promoting sustainable water use in paddy production.

Materials and Methodology

The study was conducted in Raipur district of Chhattisgarh state, which was selected purposively due to its importance of irrigated paddy cultivation. Two blocks Arang and Abhanpur were purposively selected. From each selected blocks, two villages were selected based on prevalence of the irrigation systems under study. Primary data was collected through pre tested and well structured interview schedule from 115 households which included 52 households under canal irrigation and 63 households under tube well irrigation. Secondary data was collected from CROPWAT 8.0 and CLIMWAT.

Analysis

The following tools and techniques like descriptive statistics including percentage, averages and means were used and worked out in excel.

Cropping Intensity = $\text{Gross Cropped Area} / \text{Net Sown Area} \times 100$

Cost of Cultivation: Calculated cost and returns according to CACP standards by Ministry of agriculture and farmer's welfare.

Cost A1 = all paid out costs

value of hired and permanent labour
value of machine labour (owned & purchased)
value of seed (owned & purchased)
value of fertilizer and manure
value of plant protection chemicals
irrigation charges, land revenue, miscellaneous charges
depreciation of farm implements and farm buildings
interest on working capital

Cost A2 = Cost A1 + rent paid for leased in land by households

Cost B1 = Cost A2 + interest on fixed capital

Cost B2 = Cost A2 + rental value of owned land

Cost C1 = Cost B1 + imputed value of family labour

Cost C2 = Cost B2 + imputed value of family labour

Cost C3 = Cost C2 + 10% of C2

Cost of production = Total cost / yield

Gross Income = Value of main product + Value of by product

Net Income = Gross Income - Total cost

Input Output ratio = Gross Income / Total cost

B:C ratio = Net Income / Total cost

Resource Use Efficiency

Cobb-Douglas production function was used to estimate the relationship between inputs and outputs.

$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + (v_i - u_i)$

Where,

Y_i = Crop Output (Rs), $\beta_0, \dots, \beta_7$ = Parameters to be estimated,

X_1 = Expenditure of seed (Rs)

X_2 = Expenditure of Human labour (Rs)

X_3 = Machinelabour (Rs)

X_4 = Expenditure of Irrigation (Rs)

X_5 = Expenditure of fertilizers (NPK) (Rs)

X_6 = Expenditure of Plant protection chemicals (Rs)

$v_i - u_i$ = Random error-term, and n = Number of farms growing crops

The equation was converted into linear one by taking logarithm for all the variables. Resource use efficiency was calculated using the formula,

$RUE = MVP / MFC$

Where,

MVP = Marginal Value Product; additional unit of output resulted in additional unit of input.

MFC = Marginal Factor Cost; additional unit of cost incurred for additional unit of input and was taken as 1, since all the variables are converted to its monetary value.

MVP calculated as,

$MVP = \beta_i \bar{Y}_i / \bar{X}_i$

Where,

b_i = Estimated regression coefficient of input X_i ,

$\bar{Y}_i$ = geometric mean value of output,

$\bar{X}_i$ = geometric mean value of i^{th} resource use

Decision rule: $r = 1$; Efficient use of resource

$r > 1$; Underutilization of the resource use,

$r < 1$; Overutilization of resources.

Water Use Efficiency

$WUE = \text{Yield} / \text{Crop water requirement}$

Seasonal crop water requirement of rice was estimated using the FAO CROPWAT-Online tool, based on long-term climate data for Raipur, standard rice crop coefficients, and heavy clay soil conditions.

The estimated seasonal water requirement was 630.25 mm (6,302.5 m³/ha) for paddy crop.

Garett ranking technique

Constraints faced by the farmers determined using garett ranking technique.

Percent position = $100 (R_{ij} - 0.5) / N_j$

Where,

R_{ij} = Rank given for i^{th} constraint by j^{th} respondents

N_j = Number of constraints ranked by j^{th} respondents

Results and Discussion

Socio economic profile indicating differences between households under both irrigation is provided in Table 1. Cropping Intensity of the same is calculated along with.

Table 1: Socio economic profile indicating differences between households under canal and tube well irrigation systems

S. No.	Particulars	Canal irrigation	Tube well irrigation
1	Total number of Households	52	63
2	Total Family members	446	599
3	Average Family Size	9	10
4	Average Landholding (ha)	2.07	3.14
5	Average Age of the Respondent	46	51
6	Literacy Percentage	96.15	96.83
7	Average Annual Income	168942.31	197191.78
8	Total irrigated area(ha)	105.756	226.83
9	Total gross cropped area (ha)	322.86	123.94
10	Net sown area (ha)	217.29	106.31
11	Cropping intensity (%)	148.58	116.58

Costs incurred for paddy cultivation

Cost of cultivation of paddy under canal and tube well irrigation is given in the Table 2 where highest cost was found in tube well farmers at Rs 60754.35/ha(overall) followed by canal farmers at Rs 55575.08 /ha. Upon categorization under tube well irrigation, total cost increased with increasing farm sizes with large farms incurred Rs 64417.57/ha. Highest cost under canal irrigation was also incurred by large farms with Rs 57441.37/ ha.

Seed costs showed an increasing trend in both irrigation systems with an overall costs accounted Rs 3930.04/ha and Rs 4430.44/ha respectively for canal and tube well farms. The combined costs of fertilizer and manure accounted for 12.29 and 15.41 percent of total cost each for canal and tube well farms. Slight difference was only found in plant protection chemicals costs between canal and tube well farms in overall (Rs 2156.89/ha and Rs 2455.86/ha respectively). Total labour cost including both total human labour and total machine cost were found substantially higher for canal farms, particularly small farms. Hired human labour found to be increasing with increasing farm size under both irrigation system and vice versa for family human labour. The major difference in cost was observed in irrigation charges in which Rs 225 was constant under canal irrigation whereas charges increased with increasing farm size under tube well irrigation. Miscellaneous charges were also increasing with increase in farm size under both irrigation systems. Total operational cost recorded as Rs 33642.21/ha under canal irrigation and Rs 38511.75/ha under tube well irrigation.

Total fixed costs found to have slight differences under canal and tube well irrigation which were Rs 21932.87/ha and Rs 22242.60/ha. Depreciation costs and interest on fixed capital were comparatively higher tube well irrigation while land revenue was same for all categories and both irrigation systems.

Costs in terms of Cost concepts

Cost of cultivation of paddy on the basis of cost concepts for canal and tube well irrigation is given in Table 3. Cost A1 which includes all paid out costs was found to be higher for tube well farms with Rs 35660.75/ha when compared with canal irrigation with Rs 29424.38/ha. Cost A2 was found same as Cost A1 under both irrigation systems as there were no cultivation on leased in land. Cost B1, which associated Cost A2 with interest on fixed capital was high for tube well farms than canal farms. Cost B2 had same trend like that of Cost B1 which included Cost B1 and rental value of owned land. Cost C1 which added imputed cost of family labour was

observed high for tube well (Rs 40767.58/ha) as compared to canal farmers (Rs 35545.01/ha). Same was found in the case of Cost C2 with Rs 55575.16/ha under canal irrigation and Rs 60767.58 under tube well irrigation, which adds up imputed value of family labour with Cost B2. The managerial costs, Cost C3 was high for tube well farms as compared to canal farms (Rs 61375.26/ha and Rs 56130.91/ha respectively). Additionally, Cost A2 + FL, which was Cost A2 plus the estimated cost of family labour, was Rs.34764.11/ha under canal irrigation and Rs 39846.73/ha under tube well irrigation.

Resource use efficiency of paddy

Tables 5 and 6 present the resource-use efficiency of paddy estimated using the Cobb-Douglas production function. The models showed high explanatory power, with R^2 values of 0.99 and 0.98 under tube well and canal irrigation respectively, indicating that 99 and 98 percent of output variation was explained by the input variables. The intercept was positive and significant under both systems.

Seed expenditure had a non-significant negative coefficient (-0.029) under tube well irrigation, but a significant positive coefficient (0.31, 5% level) under canal irrigation. Human labour expenditure was positive and significant under both systems, with a comparatively larger coefficient under canal irrigation, indicating its stronger influence there. Machine labour expenditure was positive and significant (10% level) under tube well irrigation (0.134) but non-significant under canal irrigation (0.01, $p=0.76$). Irrigation expenditure was non-significant under both systems (tube well: 0.001, $p=0.977$; canal: 0.04, $p=0.51$). Fertilizer expenditure was positive and significant (10% level) under tube well irrigation (0.041) but non-significant under canal irrigation, though positive in direction. Plant protection chemical expenditure was positive under both systems (0.46 and 0.03) but significant only under tube well irrigation (5% level), likely reflecting more effective pest and disease control.

Under tube well irrigation, resource-use efficiency (RUE) indicated seed was economically inefficient (-1.115), while human labour (7.008) and machine labour (3.837) were underutilized, offering scope for increased use. Irrigation showed negative RUE (-0.058), implying no benefit from additional expenditure. Fertilizer was overutilized (0.771), requiring careful management, while plant protection chemicals showed the highest underutilization (RUE 32.32), suggesting scope for increased use. Under canal irrigation, seed (2.984), machine labour (10.755), irrigation (highest RUE), and fertilizer (7.538) were all underutilized, indicating

potential for increased and more timely use, particularly of canal water. Human labour (-2.83) and plant protection chemicals (-5.774) showed negative RUE, suggesting no additional benefit from increased expenditure.

Returns from paddy cultivation

Returns obtained from paddy cultivation for different Farm sizes under canal and tube well irrigation is given in Table 4. Highest costs was observed under tube well farms in comparison with canal irrigation. Main product yield was 47.16 q/ha and 54.63 q/ha in overall under canal and tube well irrigation respectively. Around 51.87 quintals of produce was sold at Rs 3100/q which made up gross income of Rs 152327.42/ha and Rs 172659.83/ha under canal and tube well irrigation respectively.

The net income obtained by deducting total cost from gross income was highest in both large farms under canal irrigation (Rs 108580.63/ha) and under tube well irrigation. Lowest returns was found in marginal farms under both irrigation systems. Cost of production decreased with increase in farm sizes for both irrigation systems. Input Output ratio was obtained around 2.74 for canal irrigation and 2.84 for tube well irrigation in overall. At the same time, B:C ratio was also found to be high for tube well farms (1.84) when compared with canal farms (1.74).

Water use efficiency of paddy

Water use efficiency (WUE) was estimated to compare the effectiveness of water use in paddy cultivation under canal and tube well irrigation. Table 7 contains comparative WUE for different farm sizes under canal and tube well irrigations. The results showed that tube well irrigated farms achieved higher water use efficiency than canal irrigated farmers across all farm size categories, with overall mean WUE of 0.865 kg/m³ and 0.787 kg/m³, respectively. Since the crop water requirement (ETc) applied to both groups was same, being derived solely from regional climate and crop data rather than the actual quantity of water each farmer applied, this consistent gap in WUE was attributable entirely to the differences in yield produced between the two irrigation sources. Tube well farmer's ability to apply water precisely and at the crop's critical growth stages, unlike dependence on canal release schedules, appears to translate into better crop establishment and higher yields per unit of water requirement, whereas canal farmers, being subject to

rotational and often untimely water release, likely experience yield penalties during moisture-sensitive growth stages despite receiving the same theoretical water requirement.

Within each irrigation system, WUE also varied with farm size. Under canal irrigation, WUE increased from 0.762 kg/m³ in marginal farms to 0.843 kg/m³ in medium farms, followed by a slight shrink to 0.833 kg/m³ in large farms. This suggested that medium sized farms may be managing available water more efficiently, while larger farms face some difficulty in maintaining uniform water distribution. On the other hand, tube well irrigation showed a steady increase in WUE with farm size, rising from 0.777 kg/m³ in marginal farms to 0.953 kg/m³ in large farms. This was due to better access to irrigation facilities, pumping equipment, capital and improved crop management among larger tube well farmers.

Constraints

Among canal-irrigated farmers, non-availability of water during the Rabi season ranked as the major constraint, followed by uneven rainfall, untimely water release, fragmented holdings, and tail-end water shortage, reflecting uncertainty in irrigation timing and availability. For tube-well farmers, labour shortage during peak seasons was the primary constraint, followed by high maintenance charges, groundwater depletion, irregular electricity supply affecting timely irrigation, and high installation costs.

To address the problems faced by canal and tube well farmers, better coordination between the two irrigation sources is needed. Canal water should be used wherever available, while groundwater use can be regulated during periods of adequate canal supply to reduce pressure on groundwater resources. Timely release of canal water, particularly during critical crop stages, along with regular desilting and maintenance of canals and field channels, can improve water availability and reduce losses. Adequate water supply during the *Rabi* season, along with small farm-level water storage and supplementary irrigation facilities, can help improve cropping intensity and productivity. The shortage of farm labour can be addressed by making farm machinery subsidies easier to access and creating awareness among farmers about available schemes. In groundwater-stressed areas, strengthening canal infrastructure and encouraging the conjunctive use of canal and groundwater can improve irrigation reliability and support more sustainable water use

Table 2: Cost of cultivation of paddy under Canal and Tube well Irrigation (Rs/ha)

Particulars	CANAL IRRIGATION					TUBE WELL IRRIGATION				
	Marginal (27)	Small (12)	Medium (9)	Large (4)	Overall (52)	Marginal (8)	Small (15)	Medium (19)	Large (21)	Overall (63)
Seed Cost	3894.45 (7.12)	3916.35 (6.93)	4006.80 (7.11)	4038.57 (7.03)	3930.04 (7.07)	4158.78 (7.42)	4372.67 (7.59)	4413.36 (7.26)	4590.64 (6.91)	4430.44 (7.23)
Fertilizer & Manure cost	6567.02 (12.02)	7035.98 (12.45)	7037.06 (12.49)	7551.18 (13.15)	6832.30 (12.29)	8192.54 (14.62)	9866.10 (17.12)	10413.29 (17.13)	8748.04 (13.17)	9445.93 (15.41)
Plant Protection Chemicals Cost	2005.25 (3.67)	2201.23 (3.89)	2400.23 (4.26)	2500.00 (4.35)	2156.89 (3.88)	2223.28 (3.97)	2311.62 (4.01)	2505.50 (4.12)	2602.58 (3.92)	2455.86 (4.01)
Hired Human Labour Cost	5013.12 (9.18)	5603.13 (9.91)	6000.56 (10.65)	6856.75 (11.94)	5462.00 (9.83)	5052.91 (9.02)	5628.28 (9.77)	6013.20 (9.89)	7006.94 (10.55)	6130.86 (10.00)
Family Human Labour Cost	6015.74 (11.01)	5603.13 (9.91)	4000.38 (7.10)	3000.00 (5.22)	5339.73 (9.61)	6063.49 (10.82)	5065.25 (8.79)	4008.80 (6.60)	3002.98 (4.52)	4185.98 (6.83)
Total Human Labour Cost	11028.86 (20.19)	11206.26 (19.83)	10000.94 (17.75)	9856.75 (17.16)	10801.73 (19.44)	11116.40 (19.84)	10693.54 (18.55)	10022.01 (16.49)	10009.92 (15.07)	10316.84 (16.83)
Owned Machine Cost	1203.15	3802.13	4000.38	4500.00	2540.65	1212.70	3015.15	4008.80	4053.08	3431.92

	(2.20)	(6.73)	(7.10)	(7.83)	(4.57)	(2.16)	(5.23)	(6.60)	(6.10)	(5.60)
Hired Machine Cost	5514.43	3501.96	3500.33	3500.00	4546.46	4193.92	2010.10	1503.30	3503.47	2632.36
	(10.09)	(6.20)	(6.21)	(6.09)	(8.18)	(7.49)	(3.49)	(2.47)	(5.27)	(4.29)
Total Machine Cost	6717.58	7304.08	7500.70	8000.00	7087.11	5406.61	5025.25	5512.10	7556.55	6064.27
	(12.30)	(12.92)	(13.31)	(13.93)	(12.75)	(9.65)	(8.72)	(9.07)	(11.37)	(9.89)
Total Labour Cost	17746.44	18510.35	17501.64	17856.75	17888.84	16523.02	15718.79	15534.11	17566.47	16381.11
	(32.49)	(32.75)	(31.07)	(31.09)	(32.19)	(29.49)	(27.27)	(25.56)	(26.44)	(26.72)
Irrigation Charges	225.00	225.00	225.00	225.00	225.00	909.52	994.55	2584.91	5352.68	2916.09
	(0.41)	(0.40)	(0.40)	(0.39)	(0.40)	(1.62)	(1.73)	(4.25)	(8.06)	(4.76)
Miscellaneous Cost	1203.15	1350.76	1500.14	1550.00	1315.29	1148.81	1407.07	1435.54	1501.49	1414.33
	(2.20)	(2.39)	(2.66)	(2.70)	(2.37)	(2.05)	(2.44)	(2.36)	(2.26)	(2.31)
Interest on Working Capital @ 4%	1265.65	1329.59	1306.83	1348.86	1293.93	1326.24	1386.83	1475.47	1612.89	1481.22
	(2.32)	(2.35)	(2.32)	(2.35)	(2.33)	(2.37)	(2.41)	(2.43)	(2.43)	(2.42)
Total Operational Cost	32906.96	34569.25	33977.70	35070.35	33642.21	34482.19	36057.62	38362.18	41935.10	38511.75
	(60.24)	(61.16)	(60.31)	(61.05)	(60.53)	(61.55)	(62.56)	(63.12)	(63.11)	(62.81)
Depreciation	976.58	1136.60	1382.05	1391.04	1115.57	1002.04	1216.02	1395.87	1433.25	1315.50
	(1.79)	(2.01)	(2.45)	(2.42)	(2.01)	(1.79)	(2.11)	(2.30)	(2.16)	(2.15)
Land Revenue	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Interest on Fixed Capital @ 7%	683.61	795.62	967.43	973.73	780.90	701.43	851.21	977.11	1003.28	920.85
	(1.25)	(1.41)	(1.72)	(1.70)	(1.41)	(1.25)	(1.48)	(1.61)	(1.51)	(1.50)
Rented value of owned land	20052.47	20011.19	20001.88	20000.00	20030.15	20000.00	20000.00	20000.00	20000.00	20000.00
	(36.71)	(35.41)	(35.51)	(34.82)	(36.04)	(35.70)	(34.70)	(32.90)	(30.10)	(32.62)
Total Fixed Cost	21718.91	21949.66	22357.60	22371.02	21932.87	21709.71	22073.48	22379.24	22442.78	22242.60
	(39.76)	(38.84)	(39.69)	(38.95)	(39.47)	(38.63)	(37.97)	(36.84)	(34.84)	(36.61)
Total Cost	54625.87	56518.91	56335.30	57441.37	55575.08	56191.90	58131.10	60741.41	64417.57	60754.35
	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)

Table 3: Cost of cultivation of paddy in terms of Cost concepts (Rs/ha)

Particulars	Canal irrigation (52)	Tube well irrigation (63)
Cost A1	29424.38	35660.75
Cost A2	29424.38	35660.75
Cost A2+FL	34764.11	39846.73
Cost B1	30205.28	36581.60
Cost B2	50235.43	56581.60
Cost C1	35545.01	40767.58
Cost C2	55575.16	60767.58
Cost C3	56130.91	61375.26

Table 4: Returns from Paddy cultivation under canal and tube well irrigation (Rs/ha)

Particulars	CANAL IRRIGATION					TUBE WELL IRRIGATION				
	Marginal (27)	Small (12)	Medium (9)	Large (4)	Overall (52)	Marginal (8)	Small (15)	Medium (19)	Large (21)	Overall (63)
Total cost of cultivation (Rs/ha)	54625.87	56518.91	56335.30	57441.37	55575.08	56191.90	58131.10	60741.41	64417.57	60754.35
Main product (q)	45.50	47.96	49.19	51.40	47.16	47.37	49.67	54.78	60.80	54.63
Value of production (Rs/ha)	141050.00	148676.00	152489.00	159340.00	146196.60	146847.00	153977.00	167895.46	178843.46	165558.05
By product (q)	59.15	62.35	63.95	66.82	61.31	61.58	64.57	71.21	79.04	71.02
Revenue from straw (100rs/q)	5915.00	6234.80	6394.70	6682.00	6130.83	6158.10	6457.10	7121.14	7904.23	7101.78
Gross income (Rs/ha)	146965.00	154910.80	158883.70	166022.00	152327.42	153005.10	160434.10	175016.60	186747.69	172659.83
Net income	92339.13	98391.89	102548.40	108580.63	96752.26	96813.20	102303.00	114275.19	122330.12	111892.25
Cost of production (Rs/q)	1200.57	1178.46	1145.26	1117.54	1179.51	1186.23	1170.35	1108.86	1059.47	1116.86
Cost A2+ FL (Rs/q)	720.51	659.71	639.07	545.31	675.51	737.46	523.56	725.84	695.08	671.92
Input- Output ratio	2.69	2.74	2.82	2.89	2.74	2.72	2.76	2.88	2.90	2.84
B:C ratio	1.69	1.74	1.82	1.89	1.74	1.72	1.76	1.88	1.90	1.84

Table 5: Resource use efficiency of paddy using Cobb Douglas production function

Particulars	Tube well irrigation			Canal irrigation		
Input	Coefficients	S E	P-value	Coefficients	S E	P-value
Intercept	3.153	0.399	0.000	2.91***	0.41	0.01
X ₁ (Expenditure on seed)	-0.029 ^{NS}	0.055	0.605	0.31**	0.13	0.02
X ₂ (Expenditure on Human Labour)	0.431**	0.193	0.029	0.55***	0.18	0.01
X ₃ (Expenditure on machine labour)	0.134*	0.073	0.073	0.01 ^{NS}	0.04	0.76

X ₄ (Expenditure on Irrigation)	-0.001 ^{NS}	0.022	0.977	0.04 ^{NS}	0.06	0.51
X ₅ (Expenditure on Fertilizer)	0.041*	0.024	0.087	0.10 ^{NS}	0.06	0.11
X ₆ (Expenditure on Plant protection chemicals)	0.460**	0.207	0.029	0.03 ^{NS}	0.08	0.72
R square	0.99			0.98		

Note: Indicate NS as non-significant, * for 10% significance level, ** for 5% significance level, *** for 1% significance level

Table 6: Comparative resource use efficiency of paddy

Particulars	Tube well Irrigation				Canal Irrigation			
	MVP	MFC	RUE	Remark	MVP	MFC	RUE	Remark
Expenditure on seed	-1.115	1.000	-1.115	NMP	2.98	1	2.98	U
Expenditure on human labour	7.008	1.000	7.008	U	-2.83	1	-2.83	NMP
Expenditure on Machine labour	3.837	1.000	3.837	U	10.76	1	10.76	U
Expenditure on irrigation	-0.058	1.000	-0.058	NMP	272.69	1	272.69	U
Expenditure on fertilizer	0.771	1.000	0.771	O	7.54	1	7.54	U
Expenditure on PPC	32.232	1.000	32.232	U	-5.77	1	-5.77	NMP

Note: Indicate NMP as negative marginal product, U as underutilized, O as Overutilized

Table 7: Comparative analysis of water use efficiency of paddy for different farm sizes under canal and tube well irrigation (kg/m³)

Farm size	WUE of Canal	WUE of Tube well
Marginal	0.762	0.777
Small	0.788	0.852
Medium	0.843	0.860
Large	0.833	0.953
Average	0.787	0.865

Table 8: Ranking of constraints faced by canal farmers

Sl. No.	Particulars	Garrett Score	Rank
1	Unavailability of water during Rabi season	71.1	I
2	Uneven rainfall	64.8	II
3	Untimely release of canal water	59.0	III
4	Fragmented land holdings	53.1	IV
5	Tail-end water shortage	47.4	V

Table 9: Ranking of constraints faced by tube well farmers

Sl. No.	Particulars	Garrett Score	Rank
1	Shortage of labour during peak seasons	70.25	I
2	High maintenance charges of tube well and irrigation equipment	64.83	II
3	Depletion of groundwater table	58.76	III
4	Restricted/irregular electricity supply	53.41	IV
5	High installation cost of tube well	47.60	V

Conclusion

The study revealed that cost of cultivation of paddy was highest under tube well irrigation at Rs 60754.35/ha than canal irrigation at Rs 55575.08/ha. Gross income were Rs 152327.42/ha under canal irrigation and Rs 172659.83/ha under tube well irrigation. Net income was highest under tube well irrigation at Rs 111892.25/ha than under canal irrigation at Rs 96752.26/ha. The input output ratio was 2.84 under tube well irrigation and 2.74 under canal irrigation. Resource use efficiency obtained using cobb douglas production function indicated that under canal irrigation, seed, machine labour, irrigation and fertilizer marked underutilization, whereas human labour and plant protection chemicals marked over utilization. On the other hand, machine labour and plant protection chemicals were found underutilized and seed, human labour, irrigation and fertilizer were found to be over utilized under tube well irrigation. Water use efficiency was found comparatively higher for tube well farms recorded

as 0.865 kg/m³ and comparatively lesser for canal farms recorded as 0.787 kg/m³.

Suggestions

- 1. Improve canal water management** by ensuring timely and adequate water release, proper rotational scheduling, and regular desilting and maintenance of canals and field channels, with special attention to tail-end farmers.
- 2. Promote combined use of canal and groundwater**, using canal water wherever available and groundwater as supplementary irrigation to improve reliability and reduce pressure on groundwater resources.
- 3. Improve access to farm mechanization** by strengthening subsidies, awareness programmes and village level custom hiring services to address labour shortages and help small and marginal farmers access machinery.
- 4. Encourage efficient and need based input use** through soil test based fertilizer application and crop and irrigation specific recommendations for seed, labour, machinery, irrigation and plant protection chemicals.

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