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Scaling up the Performance of Irrigation Systems by Capitalising the Symbiotic Buffering Role of Tank and Groundwater Sources - An Economic Analysis in Kancheepuram District of Tamil Nadu

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ABSTRACT

Irrigation is necessary for sustaining production in agriculture and plays a key role in food security. A multitude of water sources, including surface (reservoirs, canals, tanks and check dams) and underground (groundwater by open wells and tubewells,); provide the water needed to irrigate the cropped area. Both groundwater sources and tank sources can act as buffers by their complementary and supplemental roles in water supply, and thus can serve as investments in yielding profitable returns for the farmers. Although being widespread in India and mainly concentrated in the southern states, tank irrigation has been declining in area and number over the years as their maintenance were neglected due to a shift of pattern in socio-economic and environmental factors. As a result, the increasing dependence on groundwater sources has consequently strained due to overexploitation. In changing climate scenarios, this poses significant challenges to the conservation of these valuable public goods. This work therefore seeks to study the efficiency of groundwater (tubewell source) while complementing surface source (tank irrigation) by evaluating the costs and enumerating the factors determining the income of the sample farmers. The Uthiramerur Tank Command area located in Kancheepuram district of Tamil Nadu was selected as the study area and a sample size of 120 respondents were interviewed for this research study. It was found that the cost of irrigating groundwater had decreased for the farmers who were closer to the tank command area whereas the HP capacity of the tubewells had increased with a consequent hike in the cost with increasing distance from the tank command area. This implied that farmers who were away from the tank command area deprived from the tank's buffering complementary role and had to depend only on groundwater sources. The results also showed that owning groundwater source along with utilization of the water in the tank increased the farmer's income by Rs 2, 000 per acre in paddy crop which was the predominant crop in this tank command area. The study suggested investing in conjunctive water utilization of both sources so as to minimize the cost incurred and increase the efficiency of water use.

Keywords Conjunctive water use, Groundwater, Tank, Buffer, Efficiency.

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INTRODUCTION

Water is a versatile natural resource due to its multiple uses in ecological, environmental and social aspects of human well being. It fulfils the basic needs of the people and serves as a raw material in production processes of various goods and is the key stone resource for life to exist and thrive on our planet. According to United States geological survey, water which makes up almost one-third of the face of the planet has only 2.75% to 3.1% of fresh water (Source: http://www.worldwaterday.org). Hence, judicious use of water should be mandated since water is depleting at an ever-increasing rate over the years.

Water is being given significant attention nowadays due to its proliferated usage and is depleting at an alarming rate over the years. Although water scarcity is sporadic at few places, it poses a great challenge in the future due to the changing climatic scenarios accelerated by various factors. On the other hand, the quality of water resources had degraded due to the factors such as pollution and overexploitation of water resources for domestic and commercial needs and this presents a worrying scenario for the sustainment of life on earth. Hence, mankind must realise the importance of protecting this valuable common property resource from annihilation so that the future generations must not be deprived for this essential resource.

Agriculture is dependent up on the water resources for its sustenance. Irrigated agriculture represents 20% of the total cultivated land and contributes 40% of the global food production (World Bank 2022). The water resources are being tapped by various forms which involve both natural and man-made interventions such as rainfall, surface water bodies such as percolation ponds, lakes, rivers, tanks and sub surface water resources such as groundwater. Among those water resources, groundwater is crucial as it plays the stabilization function i.e. supplement and complement the other irrigation sources especially tanks and canals thereby offsetting the demand of irrigation water. While other sources such as tank and canal are seasonal in nature, the off-season demand and augmentation of supply is met by groundwater which supplies the required water to irrigate the crops. During the periods of critical growth or throughout the years in crop production, irrigation is required for which groundwater's role is essential. About 16 to 33% groundwater for agriculture is non renewable (Wada *et al.* 2010).

Groundwater irrigation supports and enhances the livelihood security of the farmers and also increases their income. Whenever there is no possibility of existence of both surface and sub-surface sources, we have to establish the irrigation structures in combination so as to tap their complementary action benefits. This conjunctive role of both sources must be stressed upon as the structures altogether play a buffer role mutually acting in synergy for provision of water to irrigation. Conjunctive usage of water is beneficial as the irrigated portion of the command area can be increased due to precise water delivery. It provides opportunity to cultivate crops which offer high commercial value and increases the agricultural production (Jain 2016).

Hence, this study prioritized the role of groundwater irrigation in a typical tank command area. In the aspect of tank irrigation, the largest number of tanks is found in the three southern states viz. Andhra Pradesh, Karnataka and Tamil Nadu and the union territory of Pondicherry, which account for nearly 60% of India's tank-irrigated area (Sivasubramaniyan 2006). Tamil Nadu currently has around 41127 irrigation tanks where 33142 tanks are having ayacut area of less than 40 hectares and 7986 tanks with ayacut area of 40 hectares and above irrigating the area of around 372316 hectares (TN state department of Economics and Statistics 2022) which are managed by either PWD (Public Works Department) or local Panchayats (Village councils) depending on the extent of command area.

In the recent years, there has been a growing need to rejuvenate the tanks because their areas have been reduced due to factors like improper management at farm level, encroachment, unchecked siltation, pollution and urbanization, (Kuzhalarasan *et al.* 2022). In India, the share of tanks in irrigation had declined from 3.6 million hectares to 1.6 million hectares (estimated figures) per cent from 1950 up to 2019 (Ministry of Agriculture, GoI 2022). This mismanagement leads to the water stress being transferred to the ground water. In the places where there is a dominance of surface water sources at a level; say 70%, groundwater must contribute 30% to the irrigation and vice versa. But in places where groundwater sources are only present, it is difficult to establish tanks as it involves a huge investment. But the surface sources aids in groundwater augmentation, improves the water use efficiency and provide water during lean season and the electricity cost for extracting the groundwater becomes low as there is no need for digging deep aquifers thereby increasing the private benefit to farmers and social benefits such as decrease in energy consumption, reduction of energy and carbon foot print and conservation of water. In India, among the various sources of irrigation, tube well (Groundwater) source plays a dominant role which constitutes about 60% of the total irrigated area (MoSPI, GoI 2022). Moreover, out of the total electricity consumption in agriculture, the irrigation sector alone constitutes a share of 40% (Sharma *et al.* 2015).With respect to this background, this study was performed so as to assess the economic role of groundwater in Uthiramerur tank command area in Kancheepuram district of Tamil Nadu.

MATERIALS AND METHODS

Kancheepuram district having the highest number and largest area under tanks forms the universe of the study. In this district Uthiramerur block was purposively selected as it is having the highest area under tank irrigation in this district and the Uthiramerur tank is the largest one and hence this tank command area was selected. This tank command flows about 15 km in length cutting across various revenue villages. A quota sampling selection procedure was used for this study. A sample size of 30 each of head (0-5 km), middle (5-10 km), tail (10-15 km), and non- command region (above 15 km) from Uthiramerur tank command were contacted for collecting information from the farmers. The tank irrigated areas were identified with the help of institutional information. The officials were contacted from the agriculture department and PWD of Kancheepuram district and Uthiramerur block so as to get better clarity and elicit technical detail pertaining to the tanks.

Tools of analysis

Capital recovery factor

Capital recovery factor is the ratio of a constant annuity to the present value of receiving that annuity for a given length of time. The Capital Recovery Factor (CRF) of the agricultural tubewells was calculated by using the formula given as follows:

$$\text{Capital Recovery Factor (CRF)} = \frac{i\,(1+i)^n}{(1+i)^n - 1} \quad \text{(0.139- estimated value)}$$

Where, i – Interest rate (9% for long term loan) n- Estimated life of capital asset (12 years was estimated to be the life period of the tubewells) (Michael and Khepar, 1989 and Selvakumar *et al.* 2008).

This estimated CRF was used to calculate the annual fixed cost of the tubewells.

Electricity consumption and imputed energy cost

Electricity consumption was calculated by the formula,

Electricity consumption= Horse power × 0.74 kW (735 W) ×Annual running hours

The imputed cost of electricity consumed by the tubewells was calculated by the corresponding formula,

Imputed cost of electricity= Electricity consumption x Production cost (Rs 4.5/ unit for domestic use) (TANGEDCO 2022)

Multiple linear regression analysis

In order to capture the spatial influence of tank and effect of groundwater supplementation on gross income per ha of the farm, a multiple regression analysis of linear form was fitted with the identified explanatory factors where gross income per ha was the dependent variable. The model specified for the analysis is specified as follows:

$$Y = a+b_1X_1+b_2X_2+b_3X_3+b_4X_4+ b_5X_5+ e$$

Table 1. Classification of the land holdings in Uthiramerur Command.

Sl. No.	Particulars	Head	Percent	Middle	Percent	Tail	Percent	Non- command area	Percent
1	Marginal holdings (below1ha.)	14	46.67	15	50.00	18	60.00	18	60.00
2	Small holdings (1-2 ha.)	12	40.00	15	50.00	12	40.00	12	40.00
3	Medium holdings (2-10 ha)	4	13.33	0	0.00	0	0.00	0	0.00

Table 2. Farmers' possession of tubewells in the Uthiramerur tank command area.

Region	Head	Middle	Tail	Non-command Area
Average depth in Ft	100	150	200	250
5.0	4	10	0	0
7.5	1	4	5	0
Hp 10	0	1	15	15
12.5	0	0	2	15
Farmers possessing tubewells (numbers)	5 (16.67)	15 (50.00)	22 (73.33)	30 (100.00)

Where, Y - Gross income (Rs/ha of the farm), X_1 – Human and Machinery Labour (Rs/ha), X_2-Seeds (Rs/ha), X_3 – Plant protection, manures and fertilizers (Rs) and X_4 – Location dummy (Head = 3, Middle = 2, Tail = 1, non-command area = 0), X_5- Ground water possession (=1 if Yes and 0' otherwise)

a – Constant
b_1 to b_5 – Co-efficient of independent variable and
e – error term

The other tools such as descriptive statistics, percentages and averages were also used in this analysis.

RESULTS AND DISCUSSION

It could be observed from the Table 1 that the proportion of the marginal farms had increased while moving farther away from the head to the tail region of the tank command area. The higher size distribution of land holdings (medium) was observed in head region.

Calculation of electricity consumption and costs incurred in tubewell irrigation in the Uthiramerur tank command area

The particulars of the operational power of the tubewells at various command areas and the calculation of the aggregated total costs incurred at the command areas of Uthiramerur tank is given as follows:

It could be observed from the Table 2 that the farmers' possession of groundwater sources had shown an increasing trend from the head to tail region and non command area of Uthiramerur tank command. In head region, only 16.67% of the farmers possessed tubewells of their own which had increased to 50% and 73.33% in middle and tail regions whereas in the non command area, all the farmers possessed their own device.

Table 3 shows the electricity consumed by the tubewells in the various command areas of Uthiramerur tank. It is evident that with the farther movement from head to non-command area region, the electricity consumption had been increasing as indicated by the data. Non command area experienced the highest electricity consumption as it fully depended on groundwater source for irrigation. Moreover, the distribution of high HP powered motors towards the non-command area from the head region was also the

Table 3. Electricity Consumption in Tubewell irrigation of Uthiramerur Tank Command Area.

Sl. No.	Electricity consumption (watt per hour) Horse Power	Region Head	Middle	Tail	Non Command Area
1	5 Hp (3750)	4790625.00	5748750.00	6570000.00	6980625.00
2	7.5 Hp (5595)	7147612.50	8577135.00	9802440.00	10415093.00
3	10 Hp (7460)	9530150.00	11436180.00	13069920.00	13886790.00
4	12.5 Hp (9325)	11912687.50	14295225.00	16337400.00	17358488.00
	Average in watts	**8345268.75**	**10014322.50**	**11444940.00**	**12160248.75**

Table 4. Imputed Electricity costs incurred in Tubewell irrigation of Uthiramerur Tank Command Area.

Imputed Cost of Electricity Consumption (1kW= Rs.4.5)		Region			Non
Sl. No.	Horse power	Head	Middle	Tail	command area
1	5 Hp (3750)	Rs 21,557.81	25869.38	29565.00	31412.81
2	7.5 Hp (5595)	Rs 32,164.26	38597.11	44110.98	46867.92
3	10 Hp (7460)	Rs 42,885.68	51462.81	58814.64	62490.56
4	12.5 Hp (9325)	Rs 53,607.09	64328.51	73518.30	78113.20
	Average in rupees	**Rs 37,553.71**	**Rs 45,064.45**	**Rs 51,502.23**	**Rs 54,721.12**

attributing reason for the higher energy consumption and cost in the three regions.

Table 4 shows the worked out imputed cost of electricity consumed by the tubewells in the various command areas of Uthiramerur tank. The cost comparisons exhibited the same pattern as that of their energy consumption. Cost was worked out by multiplying the production cost per unit (Rs 4.5) given by TANGEDCO of Tamil Nadu government. Farmers cultivating in the non command area incurred the highest costs in consumption of electricity indicating the full dependence on groundwater sources for irrigation.

From the Table 5, it could be inferred that the annual running hours followed the same increasing trend from head to tail and non command area. Similarly, the annual fixed cost and imputed energy cost exhibited a substantial increase in magnitude from head to tail regions. The advantage of head region could be attributed to being closer to the tank and hence it benefits more from the synergistic hydro interaction of both the tank and groundwater sources.

Economic impact of location proximity and groundwater device possession in the sample farms of the study area

The effects of various explanatory variables on the gross income of the sample farms in the study area have been estimated using multiple linear regression analysis. The gross income as dependent variable and the independent variables were human and machinery cost (X_1), seeds (X_2), manures, fertilizers and plant protection (X_3), location proximity (X_4) and groundwater possession (X_5). The result of multiple linear regression analysis is tabulated below in the Table 5.

It could be inferred from the Table 6 that, all the explanatory variables exerted their influence on gross income per hectare of the farm in a significant way. It could be inferred from the results that all other paid-up inputs the manures, fertilizers and plant protection chemicals (PPC) put together had a greater influence on the gross income per ha of the farm i.e., every one rupee increases in these inputs above its mean expenditure value (2148.75) fetched an additional amount of Rs 10 per hectare of the farm almost in all cases.

The advantage of location proximity to tank irrigation source exhibited a considerable economic advantage of Rs 13241 for every 5 km nearer to tank from above 15 km to within 15 km (non-command to tail) 15km to 10km (tail to middle) and from 10km to 5km (middle to head). The possession of groundwater lifting device (tubewell) had made a positive discernible impact worth of Rs 2,059 over the average gross income and was statistically significant. The R^2 value

Table 5. Imputed electricity costs incurred in tubewell irrigation of Uthiramerur tank command area.

Annual hours of operation (Hrs)	1277.50	1533.00	1752.00	1861.50
Total investment (Rs)	64,538.43	1,44,748.70	1,84,264.80	1,99,566.9
Annual fixed cost (Rs)	9,013	20,214	25,733	27,870
Imputed energy cost	37,553.71	45,064.45	51,502.23	54,721.12
Total cost	**Rs 1,11,105.14**	**Rs 2,10,027.15**	**Rs 2,61,500.03**	**Rs 2,82,158.02**

Table 6. Multiple regression analysis of the economic impact of location proximity and groundwater device possession in the sample farms of the study area.

Sl. No.	Explanatory variable	Mean value	Co-efficient	P-value
1	Constant	-	-2969.76	0.571511
2	X_1 –Human and machinery labour (Rs/ha)	11331.67	1.39251	**0.000118*****
3	X_2 -Seeds Rs/ha	2850.00	2.031366	**0.025642****
4	X_3 - Manures, fertilizers and PPC (Rs/ha)	2148.75	10.67534	**7.95E-07*****
5	X_4- Location proximity	1.50	13241.43	**1.81E-11*****
6	X_5- Groundwater possession	0.60	2059.389	**0.04261****
	R^2		**0.82**	

** Significant at 5% level, *** Significant at 1% level.

of 0.82 explained the 82% of the variation in per ha gross income of the farm was through the attribution of the five explanatory variables fitted in the model.

CONCLUSION

From the study, it is evident that the conjunctive utilization of both surface and groundwater irrigation systems would help in offsetting the demand and augmenting the supply of irrigation water by their synergistic hydro interactions. The reduced pressure on scarce groundwater will play the timely offseason supplementary role during the critical crop growth period. It would help the farmers to reduce both farm and societal costs as they do not need to go for more deep dug wells. The existence of a tank offers multiple benefits as it adds value to the ecosystem services being offered to the community living near the vicinity. This study also suggests the farmers to go for investment in building percolation ponds or small irrigation structures in places wherever there are no such larger surface structures established and are less costly as compared to them. These surface water structures aid in recharging the groundwater table and provide support for groundwater thereby irrigating the cropped area throughout the year which might be eventually transferred out of agriculture to other important needy sectors without hampering the agricultural production.

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