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An economic analysis of irrigation ecosystem of Villupuram district of Tamil Nadu, India

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Abstract
In the irrigation ecosystem of Villupuram district of Tamil Nadu, India which has a predominance of tanks and open wells, the following investigations were carried out with a focus on economic domain namely impact on water resources, productivity of water and cost and returns of principal crop namely paddy. Hence to examine the issues in irrigation, three irrigation ecosystems were selected namely both tank water and groundwater irrigation ecosystem, tank water irrigation ecosystem and groundwater irrigation ecosystem.
Water productivity was studied with Cobb-Douglas production function, the respondents in different irrigation ecosystem faced several problems which were analysed with Garett's Ranking Technique. The results revealed that in both tank and groundwater irrigation ecosystem the irrigation intensity was highest with 204.79 percent and it was higher over tank irrigation ecosystem by 38.40 percent and over ground water irrigation ecosystem by 44.38 percent. The water availability was also high in tank and groundwater irrigation ecosystem. The water quality was average in all the three irrigation ecosystems and good water quality was dominant in ground water irrigation ecosystem. Ground water irrigation ecosystem had the best water productivity among the three irrigation ecosystems. In all the three ecosystems water productivity responded to inputs and labour which augurs for a good sound irrigation ecosystem. In all the three irrigation ecosystems, the most important problem faced was late or early rainfall. Hence Government should plan for strategies to mitigate the harmful effects of uneven rainfall in the district and Agricultural Extension Department should conduct training programme on the effective usage of inputs to increase productivity in tank and ground water irrigation ecosystems.

Keywords: Tank irrigation ecosystem, ground water irrigation ecosystem, tank and ground water irrigation ecosystem, irrigation intensity, water availability, water quality, water productivity, cost and returns and Garett's ranking technique

1. Introduction
India holds 1,20,000 tanks irrigating 43 million hectares. There are approximately 39,000 tanks of various sizes in the state of Tamil Nadu. The majority of farmers only obtain insufficient amounts of water from tanks as a result of poor tank management. Farmers have turned to additional supplies from groundwater to counterbalance the consequent drop in tank water supply to prevent crop losses (Palanisami and Easter, 1987) [1]. Groundwater irrigation increased from 30.17 percent to 55.36 percent from 1952 to 1999-2000, whereas tank irrigation decreased from 16.51 percent to 5.18 percent respectively. Over the past few years, there has been a consistent decline in the ratio of tank irrigation to net irrigation (Palanisami K., 2006) [3]. Over the course of the decade, the tanks deliver water normally for three years, insufficiently for five years, and entirely inadequately for the last two years (Palanisami, 2001) [2]. In southern India, the percentage of agricultural land irrigated by tanks decreased from 37 percent to 29 percent in the year of 1960s to 1970s, 29 percent to 22 percent in the year of 1970s to 1980s, and 22 percent to 18 percent in the year of 1980s to 1990s. In the meantime, the percentage share of private wells increased throughout the comparable periods from 20 to 26 to 31 and to 40 respectively (Kajisa *et al*. 2007) [4].
Hence to understand the irrigation ecosystem of Villupuram district, which has a predominance of tanks and open wells, the following investigations were carried out with a focus on economic domain namely impact on water resources, productivity of water and cost and returns of principal crop namely paddy.

2. Design of the study
2.1 Selection of the study area
Villupuram district is one of the foremost districts in crop production with highest production

in paddy, groundnut, pulses, and sugarcane. District highly dependent on ground water and tanks for irrigation with net irrigated area of 122532 hectares and 12449 hectares respectively. Hence to examine the issues in irrigation, three irrigation ecosystems were selected namely both tank water and groundwater irrigation ecosystem, tank water irrigation ecosystem and groundwater irrigation ecosystem. Two blocks were purposively selected for each irrigation ecosystem. In each block, four villages were selected. From each village, ten farmers were selected randomly and the total sample size was one hundred and sixty farmers. Hence multi stage random sampling was adopted for the study.

2.2 Tools of analysis

2.2.1 Descriptive analysis

The percentage analyses were used to analyse the number of irrigation, the irrigation intensity, water availability, water quality and irrigated area for the study.

2.2.2 Water productivity

The production function analysis was used to evaluate the water productivity as response of productivity to various inputs. The analysed Cobb-Douglas production function for paddy for both tank water and groundwater irrigation ecosystem, tank water irrigation ecosystem and groundwater irrigation ecosystem is given below

$$Y = a\, X_1^{b_1}\, X_2^{b_2}\, X_3^{b_3}\, X_4^{b_4}\, X_5^{b_5} X_6^{b_6} \mu_t$$

Where,
Y = Yield (kg/m^3)
X_1 = Human labour (man days / ha)
X_2 = Animal labour (hours / ha)
X_3 = Machine labour (hours / ha)
X_4 = Quantity of seeds (kg / ha)
X_5 = Quantity of fertilizer (kg / ha)
X_6 = Quantity of manure (kg / ha)
μ_t = Error term
a, $b_1, b_2, b_3, b_4, b_5, b_6$ = Parameter estimated

2.2.3. Garett's Ranking Technique

The respondents in different irrigation ecosystem of both tank and groundwater irrigation ecosystem, tank irrigation ecosystem and groundwater irrigation ecosystem in the study regions of the Villupuram district were asked to rank the problems in crop production and water distribution. In the Garrett's ranking technique these ranks were converted into percent position by using the formula

$$\text{Percent position} = \frac{100*(R_{ij} - 0.5)}{N_j}$$

Where,
R_{ij} = Ranking given to the i^{th} attribute by the j^{th} individual
N_j = Number of attributes ranked by the j^{th} individuals
By referring to the Garrett's table, the percent positions estimated were converted into scores. Thus, for each factor, the scores of the various respondents were added and the mean values were estimated. The mean values thus obtained for each of the attributes were arranged in descending order. The attributes with the highest mean value were considered as the most important one and the others followed in that order.

3. Results and Discussion

3.1. Impact of irrigation ecosystem on number of irrigation, irrigation intensity, irrigated area, water availability and water quality

The impact of irrigation ecosystem on number of irrigation, irrigation intensity, irrigated area, water availability and water quality in all the three irrigation ecosystems are discussed in this section.

3.1.1. Number of irrigation

The number of irrigation to crops is explained in Table. 1. From the table, it could be observed that paddy followed flood irrigation. In sugarcane, the number of irrigation was highest with 24 times in both tank water and groundwater irrigation ecosystem and 27 times in groundwater irrigation ecosystem. This was followed by the number of irrigation for groundnut with 12 times in both tank water and groundwater irrigation ecosystem, 9 times in tank water irrigation ecosystem and 11 times in groundwater irrigation ecosystem. Millet, pulses and Gingelly had the least number of irrigation. It could be concluded from the table that there was not much variation in the number of irrigation between different irrigation ecosystems.

Table 1: Number of irrigation in irrigation ecosystems

S. No	Crops	Tank water and groundwater irrigation ecosystem	Tank water irrigation ecosystem	Groundwater irrigation ecosystem
1	Paddy	Flood irrigation	Flood irrigation	Flood irrigation
2	Groundnut	12	9	11
3	Millets	7	6	7
4	Pulses	6	4	6
5	Sugarcane	24	---	27
6	Gingelly	4	---	6

3.1.2. Net irrigated area, gross irrigated area and irrigation intensity for irrigation ecosystems

The net irrigated area, gross irrigated area and irrigation intensity is given in the table 2. In the both tank and groundwater irrigation ecosystem, net irrigated area was 5.63 ha, gross irrigated area was 11.53 ha and the irrigation g intensity was 204.79. In the tank water irrigation ecosystem, net irrigated area was 3.69 ha, gross irrigated area was 6.14 ha and the irrigation intensity was 166.39. In the groundwater irrigation ecosystem, net irrigated area was 4.32 ha, gross irrigated area was 6.93 ha and irrigation intensity was 160.41. It could be concluded from the table that in tank and groundwater irrigation ecosystem the irrigation intensity was highest with 204.79 percent and it was higher over tank irrigation ecosystem by 38.40 percent and over ground water irrigation ecosystem by 44.38 percent.

Table 2: Net irrigated area, gross irrigated area and crop intensity for irrigation ecosystems (ha.)

S. No	Crops	Net irrigated area	Gross irrigated area	Irrigation Intensity
1.	Tank water and groundwater irrigation ecosystem	5.63	11.53	204.79
2.	Tank water irrigation ecosystem	3.69	6.14	166.39
3.	Groundwater irrigation ecosystem	4.32	6.93	160.41

3.1.3. Irrigated area of tank water and groundwater irrigation ecosystem, tank water irrigation ecosystem and groundwater irrigation ecosystem.

The irrigated area of each crop in the tank water and groundwater irrigation ecosystem, tank water irrigation ecosystem and groundwater irrigation ecosystem.is given in the table 3.

Table 3: Irrigated area of each crop in tank water and groundwater ecosystem (ha)

S. No	Major Crops	Irrigated area for tank water and groundwater irrigation ecosystem	Irrigated area for tank water irrigation ecosystem	Irrigated area for groundwater irrigation ecosystem
1	Paddy	5.40 (50.91)	3.71 (60.53)	3.44 (58.75)
2	Groundnut	2.34 (22.04)	1.29 (21.07)	0.76 (13.12)
3	Millets	0.75 (7.11)	0.60 (9.86)	0.40 (6.87)
4	Pulses	1.11 (10.52)	0.52 (8.54)	0.33 (5.62)
5	Sugarcane	0.59 (5.64)	---	0.62 (10.62)
6	Gingelly	0.40 (3.78)	---	0.29 (5.02)

It could be observed from the table that in both tank water and groundwater irrigation ecosystem, irrigated area of paddy, groundnut, millets, pulses, sugarcane, Gingelly were 5.40 ha, 2.34 ha, 0.75 ha, 1.11 ha, 0.59 ha and 0.40 respectively. The crops paddy and groundnut, were major irrigated crops with the percent of 50.91 percent and 22.04 percent respectively. In tank irrigation ecosystem, irrigated area for paddy, groundnut, millets and pulses were 3.71 ha, 1.29 ha, 0.60 ha and 0.52 ha respectively. In this ecosystem also, the major irrigated crops were paddy and groundnut with the percent of 60.53 percent and 21.05 percent.

In groundwater irrigation ecosystem, irrigated area for paddy, groundnut, millets, pulses, sugarcane, Gingelly were 3.44 ha, 0.76 ha, 0.40 ha, 0.33 ha, 0.62 ha and 0.29 ha respectively. The crops paddy and groundnut were major irrigated crops with proportion of 58.75 percent and 13.12 percent. Thus it could be concluded from the table that paddy and groundnut were the major irrigated crops in all the three irrigation ecosystem.

3.1.4. Water Availability in **tank water and groundwater irrigation ecosystem, tank water irrigation ecosystem and groundwater irrigation ecosystem**

The water availability is discussed in the table 4. The availability of water was high in both tank and ground water irrigation ecosystem with 52.20 metres in rainy season and 36.80 metres in dry season. This was followed by tank irrigation ecosystem and lastly with groundwater irrigation ecosystem. Further, the availability of water in tank water and ground water irrigation ecosystem was high in rainy season than dry season with 58.65 percent and 41.35 percent respectively.

Table 4: Water availability in irrigation ecosystems (metre)

S. No	Particulars	Tank water & Groundwater irrigation ecosystem	Tank water irrigation ecosystem	Groundwater irrigation ecosystem
1	Rainy season	52.20 (58.65)	33.10 (61.41)	22.20 (53.75)
2	Dry season	36.80 (41.35)	20.80 (38.59)	19.10 (46.25)
	Total	89.00 (100.00)	53.90 (100.00)	41.30 (100.00)

In the tank water irrigation ecosystem, the availability of water was 61.41 percent in rainy season and 38.59 percent in dry season. The availability of water in ground water irrigation ecosystem was high in rainy season with 53.75 percent and less in dry season with 46.25 percent. Thus it could be concluded from the table that water availability was also high in tank and groundwater irrigation ecosystem and in all the ecosystems, the water availability was high in rainy season.

3.1.5. Water Quality in tank water and groundwater irrigation ecosystem, tank water irrigation ecosystem and groundwater irrigation ecosystem

The water quality was classified into three categories of good, average and poor for irrigation purposes. The water quality results are given in the table 5. It could be inferred from the table that in all three types of irrigation ecosystem, the average water quality was dominated. In the tank water and groundwater irrigation ecosystem, the average quality water was 45.00 percent in both rainy and dry season. Next, the poor quality water followed with 35.00 percent and 30.00 percent in rainy and dry season respectively. Then, the good quality followed with 20.00 percent and 25.00 percent of rainy and dry season respectively. In the tank water irrigation ecosystem, the average quality of water was high in rainy season with 50.00 percent but in dry season poor quality water was dominated with 55.00 percent. The result showed that 25.00 percent in rainy season and 20.00 percent farms in dry season water were good for irrigation.

Table 5: Water quality of sample farmer (percent)

S. No	Particulars	Tank water & Groundwater irrigation ecosystem		Tank water irrigation ecosystem		Ground water irrigation ecosystem	
		Rainy Season	Dry season	Rainy Season	Dry season	Rainy Season	Dry season
1	Good	20.00	25.00	25.00	20.00	40.00	30.00
2	Average	45.00	45.00	50.00	25.00	45.00	50.00
3	Poor	35.00	30.00	25.00	55.00	15.00	20.00
	Total	100.00	100.00	100.00	100.00	100.00	100.00

In the groundwater irrigation ecosystem, the average quality was dominated with 45.00 percent and 50.00 percent of rainy and dry season respectively. Next, the good quality followed with 40.00 percent and 30.00 percent of rainy and dry season respectively. Finally, the poor quality water followed with 15.00 percent and 20.00 percent of rainy and dry season respectively. Thus, it could be inferred from the analyses that water quality was average in all the three irrigation ecosystems and good water quality was dominant in ground water irrigation ecosystem.

3.2. Water productivity of tank water and ground water irrigation ecosystem, tank water irrigation ecosystem and groundwater irrigation ecosystem

Water productivity is determined by the ratio between yield and irrigated water and the results are given in the table 6. From the table it could be revealed that groundwater irrigation ecosystem had highest water productivity followed by tank water and groundwater irrigation ecosystem and tank water irrigation ecosystem with the productivity of 17.35 kg per hour irrigation, 12.36 kg per hour irrigation and 8.23 kg per hour irrigation respectively. Thus it could be inferred from the table that ground water irrigation ecosystem had the best water productivity among the three irrigation ecosystems.

Table 6: Water productivity of both tank and ground water, tank water irrigation ecosystem and groundwater irrigation ecosystem

S. No	Irrigation ecosystem	Water productivity (Kg/hrs. of irrigation)
1	Tank water & Ground water irrigation ecosystem	12.36
2	Tank water irrigation ecosystem	8.23
3	Ground water irrigation ecosystem	17.35

The Cobb-Douglas production function was used to analyse the input elasticity with water productivity. The analysed Cobb-Douglas production function for paddy for the tank water and groundwater irrigation ecosystem, tank water irrigation ecosystem and groundwater irrigation ecosystem were given in tables 7.

Table 7: Water productivity of irrigation ecosystems

S. No	Variables	Tank & Groundwater irrigation ecosystem		Tank irrigation ecosystem		Ground water irrigation ecosystem	
		Regression coefficient	t-values	Regression coefficient	t-values	Regression coefficient	t-values
1.	Human Labour (Hrs.)	0.22*	1.40	0.36*	1.15	0.07*	0.52
2.	Animal Labour (Hrs.)	0.01	0.86	0.02	0.37	0.01	1.03
3.	Machine Labour (Hrs.)	0.03*	0.37	0.12**	0.21	0.07**	1.44
4.	Seed Qty. (Kg.)	0.34*	2.12	0.28*	0.54	0.29*	2.36
5.	Fertiliser (Kg.)	0.02**	0.18	0.16**	0.42	0.12**	0.34
6.	Manure (Qtl.)	0.09**	0.90	0.17*	1.29	0.14**	1.23
$\overline{R^2}$		0.71		0.73		0.75	
N		40		40		80	

**Significant at 1.00 percent level; *Significant at 5.00 percent level

It could be seen from the table that in both tank and ground water irrigation ecosystem, the adjusted coefficient of multiple determination $(\overline{R^2})$ was 0.71 revealing that the production model was a good fit. The value of 0.71 indicated that 71.00 percent of the variables in productivity was determined by independent variables included in the model. The coefficient in the log linear production function represents the productive elasticity of the various inputs of human labour, animal labour, machine labour, seed, fertilizer, and manure. The coefficient of fertilizer and manure was positive and significant at the 1.00 percent level, with values of 0.02, and 0.09, respectively. This meant that if the use of fertilizer and manure were increased by 1.00 percent above the mean level, the crop yield would increase by 2.00 percent and 9.00 percent respectively. The coefficient of human labour, machine labour and seed was positive and significant at the 5.00 percent level, with values of 0.22, 0.03 and 0.34 respectively. This meant that if the use of fertilizer and manure were increased by 1.00 percent above the mean level, the crop yield would increase by 22.00 percent, 3.00 percent and 34.00 percent respectively. Thus it could be inferred from the table that the water productivity dependent on all inputs and labour except the animal labour in this ecosystem.

It could be seen from the table that adjusted coefficient of multiple determination $(\overline{R^2})$ was 0.73 revealing that the production model was a good fit. The value of 0.73 indicated that 73.00 percent of the variables in productivity was determined by independent variables included in the model. The coefficient of fertilizer and machine labour was positive and significant at the 1.00 percent level, with values of 0.16, and 0.12 respectively. This meant that if the use of fertilizer and manure were increased by 1.00 percent above the mean level, the crop yield would increase by 16.00 percent and 12.00 percent, respectively. The coefficient of human labour, seed and manure was positive and significant at the 5.00 percent level, with values of 0.36, 0.28 and 0.17 respectively. This meant that if the use of fertilizer and manure were increased by 1.00 percent above the mean level, the crop yield would increase by 36.00 percent, 28.00 percent and 17.00 percent respectively. Thus it could be inferred from the table that the water productivity dependent on all inputs and labour except the animal labour in this ecosystem as like the previous ecosystem.

It could be seen from the table that adjusted coefficient of multiple determination $(\bar{R}^2)$ was 0.75 revealing that the production model was a good fit. The value of 0.75 indicated that 75.00 percent of the variables in paddy yield was determined by independent variables included in the model. The coefficient of machine labour, fertilizer and manure was positive and significant at the 1.00 percent level, with values of 0.07, 0.12 and 0.14, respectively. This meant that if the use of fertilizer and manure were increased by 1.00 percent above the mean level, the crop yield would increase by 7.00 percent, 12.00 percent and 14.00 percent, respectively. The coefficient of human labour and seed was positive and significant at the 5.00 percent level, with values of 0.07 and 0.29 respectively. This meant that if the use of human labour and seed were increased by 1.00 percent above the mean level, the productivity would increase by 7.00 percent and 29.00 percent respectively. Thus it could be inferred from the table that the water productivity dependent on all inputs and labour except the animal labour in this ecosystem as like the previous two ecosystem. Thus in all the three ecosystems water productivity responded to inputs and labour which augurs for a good sound irrigation ecosystem. Similar study was conducted by Palanisami (2020) [5] who explored the water productivity of tank irrigation and ground water in Srivilliputhur tank in Ramanathapuram District, Tamil Nadu. The physical water productivity was highest at the by farm level irrigation water (0.30 kg/m3),

3.3. Cost and returns of tank water and ground water, tank water and ground water irrigation ecosystem

The cost and return for the principal crop of paddy in both tank water and groundwater irrigation ecosystem, tank water irrigation ecosystem and groundwater irrigation ecosystem are given in table 8. It could be seen from the table that the both tank water and ground water irrigation ecosystem got highest gross income as compared with other types of irrigation ecosystem. However, net income was very low as compared with other irrigation ecosystem because total cost of both tank water and ground water irrigation ecosystem was high. The tank water and groundwater irrigation ecosystem got gross income of ₹ 208609.00, total cost of ₹ 152780.00 and net income of ₹ 55829.00.

The tank irrigation ecosystem had ₹ 150657.00 gross income, ₹ 66708 total cost and net income of ₹ 83949.00. The ground water irrigation ecosystem had ₹ 195724.00 gross income, ₹ 107862.00 total cost and net income of ₹ 87862.00. The net income was high in ground water irrigation ecosystem than both tank and ground water irrigation ecosystem by 57.37 percent and tank irrigation ecosystem by 4.66 percent respectively. Thus it could be inferred from the analyses that ground water irrigation ecosystem is highly economically profitable due to highest water productivity in this ecosystem with 17.35 kg per hour irrigation. (Vide table 6)

Table 8: Cost & return of principal crop of paddy in irrigation ecosystems

S. No	Particulars	Tank and Groundwater irrigation ecosystem	Tank irrigation ecosystem	Ground water irrigation ecosystem
1	Fixed cost	10604.00	15138.00	11890.00
2	Variable cost	142176.00	51570.00	95972.00
3	Total cost	152780.00	66708.00	107862.00
4	Gross income	208609.00	150657.00	195724.00
5	Net income	55829.00	83949.00	87862.00

3.4. Constraints of tank water and groundwater irrigation ecosystem, tank water irrigation ecosystem and groundwater irrigation ecosystem farmers

The farmers in the study area faced several problems in both tank water and groundwater irrigation ecosystem. The constraints faced by the sample farmer were ranked by using Garrett's ranking technique and the results are presented in table 9. It could be seen from table that first severe problem faced by both tank water and ground water irrigation ecosystem farmers was late or early rainfall. The second most problem was uncleaned channel, and then credit non-availability. This was followed by the problems of high wage rate, drainage facilities, over irrigation by other farmers and salty water. In tank irrigation ecosystem, first severe problem faced was late or early rainfall. The second most problem was uncleaned channel, and then over irrigation. This was followed by other problems of high wage rate, drainage facilities, crop credit non-availability and salty water. It could be seen from table that first severe problem faced by ground water irrigation ecosystem farmer was late or early rainfall. The second most problem was price fluctuation and then pest attack. This was followed by water non-availability, high wage rate, crop credit and salty water.

Table 9: Constraints of tank water and groundwater irrigation ecosystem, tank water irrigation ecosystem and groundwater irrigation ecosystem farmers.

S. No	Constraints	Tank water & Groundwater irrigation ecosystem	Tank water irrigation ecosystem	Ground water irrigation ecosystem
1	Late / early rainfall	1 (96.80)	1 (92.40)	1 (87.15)
2	Uncleaned channel	2 (79.00)	2 (79.00)	4 (60.00)
3	Credit non availability	3 (74.00)	6 (62.70)	2 (72.00)
4	High wage rate	4 (70.00)	4 (70.00)	3 (65.00)
5	Drainage facility	5 (64.00)	5 (64.00)	5 (52.25)
6	Over irrigation by other farmers	6 (61.00)	3 (74.00)	6 (51.00)
9	Salty water	7 (56.00)	7 (56.00)	7 (36.00)

4. Summary and Conclusion

In the irrigation ecosystem of Villupuram district of Tamil Nadu, India to examine the issues in irrigation, three irrigation ecosystems were selected namely both tank water and groundwater irrigation ecosystem, tank water irrigation ecosystem and groundwater irrigation ecosystem. The results revealed that in both tank and groundwater irrigation ecosystem the irrigation intensity and also the water availability was high in this ecosystem. The good water quality was dominant in ground water irrigation ecosystem. Ground water irrigation ecosystem had the best water productivity among the three irrigation ecosystems. In all the three irrigation ecosystems, the most important problem faced was late or early rainfall. Hence Government should plan for strategies to mitigate the harmful effects of uneven rainfall in the district and Agricultural Extension Department should conduct training programme on the effective usage of inputs to increase productivity in tank and ground water irrigation ecosystems.

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