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Common Property and Private Prosperity: Tanks vs. Private Wells in Tamil Nadu

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I

INTRODUCTION

Tank irrigation is one of the oldest sources of irrigation in India and is particularly important in South India, where it accounts for about one-third of the rice irrigated area. Currently, however, the performance of these tanks is poor due to inadequate operation and maintenance, large scale development of groundwater sources, disintegration of traditional irrigation institutions, heavy siltation, encroachment, etc. The neglect of tanks has meant that most farmers receive inadequate quantities of water from tanks. To offset the decline in tank water supplies, the farmers have resorted to supplemental well irrigation to avoid crop losses. Since only about 15 per cent of the farmers in the tank command area own wells, and there is a growing demand for well water, the well owners in most cases act like local monopolists and are able to charge high prices for well water. However, profit making through privately owned water source (i.e., wells) within the hydrological boundary of the common property resource (tanks) poses serious threat to the very survival of the tanks, because of the declining interest among well owners in proper upkeep of tank structures. The level of well interference on tank performance is also different in Panchayat and PWD (Public Works Department) tanks. In this paper, an attempt has been made to analyse the performance of Panchayat and PWD tanks under different levels of well irrigation and the consequences of well irrigation in tank commands. Various aspects of tank water supply, well distribution in tank commands, and the interrelationship between these variables and the overall tank performance are discussed in detail. The analyses and the discussion in this paper are based on the detailed survey covering 566 tanks in four tank-intensive districts spread over both northern and southern Tamil Nadu and the data pertained to the five-year period from 1989-90 to 1993-94.

II

METHODOLOGY

In the first stage of sampling, the districts were selected; in the second and the third stage, the tanks and the sample farms were selected respectively. The tanks were selected from both the northern (North Arcot and Chengalpattu districts) and southern (Tirunelveli and Sivagangai districts) regions of the state. Though the original study has included a total 690

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tanks, 124 sample tanks selected from the four less-tank intensive districts have been omitted from the present analysis since the tank irrigation has negligible role in those districts. For the farm level study on water management, input use and productivity, a sub-sample of 138 tanks were selected from the total number of 566 tanks selected for detailed tank level study. Out of these 138 tanks, 89 were Panchayat tanks [command area less than 40 hectares (ha)] and 49 were PWD tanks (command area more than 40 ha). In each of these 138 tanks, six farms - three in head reach and three in tail reach - were selected randomly for the farm level data collection, thus making a total number of 828 farms for the farm level study. All the tank level data presented in this paper are the five-years average from 1989-90 to 1993-94, while the farm level data relate to the two-year period from 1992-93 to 1993-94. The total number of Panchayat Union (PU) and PWD tanks and the number of tanks selected for the study in the sample districts are presented in Table 1.

TABLE 1. DISTRICTWISE DISTRIBUTION OF SAMPLE TANKS

Sr. No.	District	Total tanks		Tanks selected	
		PU	PWD	PU	PWD
(1)	(2)	(3)	(4)	(5)	(6)
1.	Sivagangai	3,882	711	172	30
2.	Tirunelveli	1,797	373	74	17
3.	North Arcot	1,916	954	80	40
4.	Chengalpattu	2,266	1,362	97	56
	Total	9,861	3,400	423	143

III

MANAGEMENT OF TANKS

In ancient days, the tanks were considered to be the property of rulers. The farmers paid a portion of the produce to the rulers and they were also in charge of the maintenance of tanks and supply channels. The Zamindars ensured the proper maintenance of tanks and channels, since they reaped the benefits of farming in large areas. However, when the British introduced the Ryotwari system of land tenure in 1886, tanks with a command area of 40 ha and above were brought under the control of PWD and smaller tanks with a command area of less than 40 ha were under the administrative control of local bodies, or vested with the villagers themselves. The farmers attended routine maintenance works under the *kudimaramathu* system (traditional system of community management of irrigation tanks). However, in the past few decades the farmers' involvement in *kudimaramathu* had declined.

Several factors contributed for the decline in the *kudimaramathu* system. These include (a) changes in the land holding pattern in the tank commands, not only in terms of the sub-division and fragmentation of lands in the tank command but also the vast changes in the caste composition of landowners (Janakarajan, 1993). (b) In early periods, the *kudimaramathu* system had the support of the Zamindari system that reinforced the then prevailing feudal social relations. With the abolition of the Zamindari system, the newly emerged social relations were no longer conducive to the communal maintenance of tanks (MIDS, 1986, pp. 145-148 quoted in Singh, 1994, p. 226). (c) The handing over of tank maintenance of the PWD was also another important reason for the decline of communal management - the PWD engineers were not empowered to enforce *kudimaramathu* (Agarwal and Narain, 1997, p.261), and the farmers were tempted to believe that with the creation of the PWD the tank maintenance is no longer their duty but it is the state's responsibility (Gomathinayagam *et al.*, 1994; Ramanathan, 1989, pp. 250-253). And (d) high levels of taxation and appropriation by the state of allocations for various social institutions, including tank repairs have also been cited as the reasons for the reluctance of the farmers to take up *kudimaramathu*. With the decline in *kudimaramathu* (Sankari, 1991) system, tanks got silted up and supply and distribution channels were choked. The deterioration of the tank irrigation system has been a subject of considerable discussion, at least since the middle of the 19th century.

The performance of tanks at present is influenced by both the level of management and the physical attributes of the system. The management factors include the presence of Water Users' Organisation, the level of operation and maintenance expenditure and the resource mobilisation from tank usufructs.[1] The hysical attributes include encroachment, siltation, well density (number of wells per hectare of command area), and the condition of tank structures such as tank bunds, sluices, surplus weir, etc. In PU tanks, the farmers have the direct responsibility for managing the system as well as water distribution and in PWD tanks, the PWD is responsible for the system management including the major repairs of the tank structures and the responsibility for water distribution is still vested with the farmers. Among the physical attributes encroachment and siltation are related to above-outlet issues involving non-beneficiaries of the tanks, whereas well density is a direct function of tank water supply and it is a below-outlet issue involving only the tank beneficiaries. Hence, it is important to highlight the influence of physical as well as management attributes. The following sections deal with the tank performance as influenced by the intensity of wells, operation and maintenance (O & M) expenditure, resource mobilisation, encroachment and the farmers' participation in the tank maintenance works.

IV

TANK PERFORMANCE AND RELATED FACTORS

Tank Performance

The tank performance is generally measured as the ratio of actual area irrigated by the tank to the total command area. This definition, however, does not purely reflect the actual tank performance since the wells in the tank command also contribute for tank performance both as a supplementing source in the wet season and as a sole source of irrigation during the dry season. Further, the data on area irrigated exclusively by wells and tanks are not available at the tank level from the village records. Also higher number of wells reflect the uncertainty in tank water supply and the farmers' ability to cope with the deficit supply compared to tanks with adequate water supply whose dependence on wells will be comparatively less. In many parts of the state such as in North Arcot district, there is strong evidence to show that the excessive growth of wells has contributed for the decline in the *real* performance[2] of tanks. Hence, comparing the performance of tanks without accounting for the positive/negative influence of the wells will be misleading. Therefore, the tank performance was redefined by excluding the probable area accounted for by the number of wells which are above the threshold number[3] of wells (sample mean) in the tank command and the adjusted tank performance was calculated for each tank. Here, only for those tanks having the well density above the threshold level, the actual area irrigated by the tanks has been calculated by subtracting the actual area irrigated by the number of wells above the threshold number, from the total area irrigated in the tank command. Hence, the Adjusted Tank Performance (ATP) is:

$$\text{ATP} = \frac{[\text{ Total area irrigated in the tank command - Area irrigated by those number of wells above the threshold number }]}{[\text{Total command area of the tank}]}$$

if well density is higher than the sample mean well density, and

$$\text{ATP} = \frac{\text{Actual area irrigated by the tank}}{\text{Total command area of the tank}}$$

if well density is less than the sample mean well density,

Well Density in Tank Commands

The well density (number of wells per hectare of command area) was relatively higher in PU tanks (0.42) than in PWD tanks (0.35), and these were not statistically different (Table 2). The reason for higher number of wells in PU tanks is that the duration of water supply is comparatively lesser in PU tanks (2-3 months) than in PWD tanks (3-5 months).

TABLE 2. FREQUENCY DISTRIBUTION OF SAMPLE TANKS BASED ON WELL DENSITY

Tank type	Well density (number of wells/ha of command area)				
	0	0.01-0.10	0.11-0.50	>0.50	Mean well density
(1)	(2)	(3)	(4)	(5)	(6)
PU	96 (24.81)	39 (10.08)	150 (38.76)	102 (26.36)	0.42
PWD	8 (4.55)	39 (22.16)	86 (48.86)	43 (24.43)	0.35

Note: Figures in parentheses are percentages to the total number of tanks.

Factors Affecting Tank Performance

The various parameters inflencing the tank performance are given in Table 3. The well density had negative influence on the tank performance. It was observed that the higher the well density, the lesser was the tank performance. Tanks without the well supplementation in the tank season had performed well and this clearly indicated the availability of adequate tank water supplies.

TABLE 3. PARAMETERS INFLUENCING TANK PERFORMANCE UNDER DIFFERENT LEVELS OF ADJUSTED TANK PERFORMANCE

Tank type (1)	Well density (No./ha) (2)	Adjusted tank performance (per cent) (3)	O & M expenditure (Rs./ha/year) (4)	Resource mobilised (Rs./ha/year) (5)	Encroachment (per cent of water spread area) (6)	Farmers' participation (man-days/ha/year) (7)
PU	1.30	<25	73.80	28.00	34.44	0.28
	1.00	25-50	12.07	0.60	20.26	0.20
	0.30	50-100	154.00	8.25	12.24	0.56
	0.00	>100	24.00	0.00	8.22	0.72
Mean	0.42	75.70	154.00	9.00	16.23	0.54
PWD	1.25	<25	28.50	68.80	19.76	0.09
	1.00	25-50	108.00	61.30	11.66	0.35
	0.30	50-100	73.20	9.45	6.99	0.49
	0.00	>100		No tank under this category		
Mean	0.35	83.30	74.00	14.00	10.23	0.30

Concerning the O & M expenditure on tanks at the state level, though outlay per hectare of command area at current prices increased from Rs. 26 to Rs. 161 per ha, the outlay at constant (1980-81) prices has increased only marginally from Rs. 33 to Rs. 43 per ha (Palanisami *et al.*, 1997). However, the level of O & M amount spent on the sample tanks revealed that the average amount spent was high for PU tanks (Rs. 154/ha) compared to PWD tanks (Rs. 74/ha). Since the O & M amount was spent mainly depending upon the urgency of the tank repair and the local political pressure, the level of tank performance and the amount of O & M spent could not be directly related.

In view of the inadequate financial support from the state for tank maintenance, the farmers mobilise financial resources for tank maintenance from tank usufructs. The major sources of income are: (a) sale of fishes raised in tank water, (b) sale of trees grown on the tank bunds and the water spread area, (c) sale of silt, and (d) collection of fees/rents from duck-growers and cattle growers for allowing the ducks and cattle in the tank command area after harvesting of rice crop, etc. Classification of parameters influencing tank performance under different levels of tank performance revealed that there is a negative relationship between resource mobilised and the tank performance. The resource mobilised per hectare of command area was found to be higher in tanks with poor performance. The resource mobilisation was Rs. 28 per ha in PU tanks and Rs. 68.80 per ha in PWD tanks with performance less than 25 per cent. The resource mobilisation was about Rs. 8.25 to Rs. 9.50 in tanks (both PU and PWD) with performance between 50-100 per cent. The major reasons for the poor performance and lower resource mobilisation in PU tanks might be the higher density of wells and lower tank water supply in PU tanks which are the two important factors restricting the tank performance.

Since resource mobilisation is a reflection of co-operative effort among the tank beneficiaries, the less number of water users' organisations in PU tanks could, in part, explain the poor resource mobilisation. Further, the PU tanks are supposed to be maintained by the

Panchayats, which have the peoples' representatives. However, for a very long time and till the completion of the data collection for the study, the Panchayats did not have the elected representatives because no elections were conducted to the local bodies in the state. It was only in 1996 the elections were held and the peoples' representatives have been elected to the local bodies. Hence, in the absence of elected representatives in the local bodies, there are strong reasons to believe that there could not have been significant qualitative difference between the management of tanks by the PU and PWD. Another plausible reason for the poor performance of the Panchayat-managed tanks might be the higher encroachment and well density in PU tanks as compared to the PWD tanks.

Further, the percentage of the PU tanks having water users' organisation was lower when compared to the PWD tanks. As much as 31 per cent of the PWD tanks had informal water users' organisation, whereas only 14 per cent of the PU tanks had informal water users' organisation. The functions of these organisations include the appointment of *neerkattis* (common waterman), organising and co-ordinating tank maintenance works (mainly cleaning supply channels and main canals), resource mobilisation for tank maintenance, lobbying with government departments for better maintenance of tank structures, etc. The farmers' participation in tank maintenance was also comparatively higher in PU tanks (0.54 man-days/year/ha of command area) than in PWD tanks (0.30 man-days/year/ha of command area). The results had indicated that the performance of tanks and the farmers' participation were directly related. In the case of encroachment in the catchment, supply channel and water spread area, it was higher (16.23 per cent) in PU tanks as compared to only 10.23 per cent in PWD tanks. The results had indicated that the level of encroachment directly influenced the performance of tanks. Because of lesser catchment, foreshore and water spread area in the case of the PU tanks, the encroachment level in a relative sense was higher. Further, since the PU tanks are smaller in size with less number of farmers, the aggression of the encroachment was also comparatively higher.

The exact relationship between tank performance and various parameters affecting the tank performance is indeed complex in nature and hence regression analysis is used to capture these interrelationships. Using ATP as dependent variable, multiple linear regression equation was estimated to identify the factors influencing the tank performance. The equation is:

$$ATP = a + b_1\,FPART + b_2\,OME + b_3\,REV + b_4\,ENC + b_5\,WELL$$

where ATP = adjusted tank performance in per cent,
FPART = farmers' participation in tank maintenance works (five years' mean in man-days/year),
OME = O & M expenditure (five years' mean in Rs./ha.),
REV = resource mobilised for tank maintenance (five years' mean in Rs./ha.),
ENC = encroachment in tank water spread and foreshore area (per cent), and
WELL = number of wells per ha of command area.

The regression coefficients are presented in Table 4. Even though R^2 was 0.37 for PU tanks, it is found to be statistically significant at 1 per cent level. The variables, viz., O & M expenditure by the Panchayats, density of wells in the tank command, the farmers' participation and encroachment are found to be statistically significant. Using the regression coefficient, the elasticities were worked out which indicated that one per cent increase in the O & M expenditure could decrease the ATP by 0.003 per cent. And an increase in the density of well above the mean level by one per cent could reduce the tank performance by 0.07 per cent and an increase in encroachment above the mean level by one per cent could decrease the tank performance by 0.20 per cent. An increase in the farmers' participation in tank maintenance by one per cent could increase the adjusted tank performance by 0.45 per cent.

TABLE 4. PERFORMANCE ANALYSIS OF PU AND PWD TANKS
DEPENDENT VARIABLE: ADJUSTED TANK PERFORMANCE

Sr. No.	Independent variables	PU tanks		PWD tanks	
		Regression coefficients	t-value	Regression coefficients	t-value
(1)	(2)	(3)	(4)	(5)	(6)
1.	Farmers' participation (man-days/ha/year)	0.025	1.89*	0.0412	1.786*
2.	O & M expenditure (Rs./ha/year)	-0.00002	-3.34**	0.00001	3.34^{NS}
3.	Resource mobilised (Rs./ha/year)	-0.000064	-1.07	-0.00008	-0.67
4.	Encroachment (per cent)	-0.0095	-2.75**	-0.0041	0.33^{NS}
5.	Well density (wells/ha)	-0.1328	-8.21**	-0.2631	-7.34**
		R^2=0.37	F=39.60**	R^2= 0.47	F = 0.00**

Note: * Significant at 5 per cent level: ** Significant at 1 per cent level: NS = Not significant.

The negative coefficient for the O & M expenditure on tank performance might be due to the increased investment by tank management authorities on poorly performing tanks but without significant revival in the performance of those tanks wherein the farmers might have already switched over to private investments such as wells. There are two other reasons: (a) The tank management authorities in the state do not take up regular maintenance works based on the needs. Due to severe financial constraints faced by both the government (PWD) and the Panchayats, the tank repair works are taken up only on a rotation basis, i.e., once in five years. And (b) the tank maintenance/repair works are prioritised purely on technical grounds without due regard to the institutional factors such as the improvements in irrigation institutions. This argument seems to be supported by the fact that the PU tanks that had higher density of wells performed poorly, as compared to the PWD tanks. The non-significance of the resource mobilisation variable is due to the fact that the resources mobilised by the farmers from the tank usufructs were higher in defunct/very poorly functioning tanks. Further, the revenue mobilised in more than 80 per cent of the tanks was spent for unproductive purposes such as temple repairs, celebration of village festivals and other common village expenditures not directly related to the tanks.

The R^2 for PWD tanks was 0.47 and it is comparatively higher than that for PU tanks. Two of the five independent variables are statistically significant, viz., well density and the farmers' participation in tank maintenance. The regression coefficients indicate that one per cent increase in the well density above the mean level could reduce the performance by

0.11 percent and one per cent increase in the farmers' participation could increase the tank performance by 0.37 per cent. Thus both in PU and PWD tanks, the influence of well density and other associated factors on tank performance was clearly demonstrated.

V

SUPPLEMENTAL WELL IRRIGATION AND RICE YIELD

Given the influence of well density on the overall performance of the tanks at the macro level, it is equally important to analyse the effect of supplemental well irrigation at the micro level (farm level). This needs to be done partricularly in terms of yield response of rice to supplemental irrigation as well as the share of non-well owners' income to the well owners' income as this will indirectly affect the tank performance. This will also indicate how the individual well owners' actions benefit their own ends while cumulatively accounting for the decline of tanks. Hence, a detailed analysis of rice production in well and non-well owning farms and the role of water markets was done.

Rice yields were estimated for sample farms that used different levels of supplemental well irrigation. The rice yield in farms without supplemental well irrigation was significantly higher at 4,131 kg/ha in PWD tanks, as compared to only 3,628 kg/ha in PU tanks. The response to supplemental well irrigation in general is higher in PU tanks than in PWD tanks. The mean rice yield was 5,277 kg/ha in PU tanks and 5,147 kg/ha in PWD tanks when the number of supplemental well irrigation was 13-15. When supplemental well irrigation exceeded 15, there was negative response in yield in both the PU tanks and PWD tanks. However, the rice yield in PU tanks was significantly higher at 4,894 kg/ha, while it was only 4,348 kg/ha in PWD tanks, when the number of supplemental well irrigation exceeded 15. The higher yield response for supplemental well irrigation in PU tanks might be due to the significantly lower base yield (i.e., yield with no supplemental well irrigation) in PU tanks than in PWD tanks due to poor water supply from PU tanks (Table 5).

TABLE 5. NUMBER OF SUPPLEMENTAL WELL IRRIGATION AND RICE YIELD

Sr. No. (1)	Number of supplemental well irrigation (2)	Rice yield (kg/ha) PU tanks (3)	Rice yield (kg/ha) PWD tanks (4)
1.	0	3,628 (361)	4,131 (167)
2.	1-3	3,514 (4)	Nil
3.	4-6	3,529 (14)	3,771 (19)
4.	7-9	Nil	3,829 (7)
5.	10-12	4,385 (10)	4,332 (8)
6.	13-15	5,277 (21)	5,147 (11)
7.	>15	4,894 (52)	4,348 (37)

Note: Figures in parentheses indicate the number of farms reporting respective yields.

Rice Production Function

The contribution of different factors to the rice yield and the interrelationships among these factors were studied using the production function approach. After a careful consideration of various factors influencing rice yield, the following form of production function was chosen to identify the nature and extent of contribution of different factors influencing rice yield. For the purpose of analysis, the number of irrigation was converted into quantity of water in hectare-centimetre (hacm) by multiplying the number of irrigation with the average depth of irrigation measured in selected locations. The per hectare production function was used to capture the effect of various inputs on the rice productivity per unit of land.

$$\text{RICEYD} = a_0+b_1\,\text{REG}+b_2\,\text{REACH}+b_3\,\text{LAB}+b_4\,\text{FYM}+b_5\,\text{TANK}+b_6\,\text{WELL} +b_7\,\text{TTYPE}+b_8\,\text{SQWELL}+ b_9\,\text{NTGN}+b_{10}\,\text{WUO}$$

where RICEYD = Rice yield in kg/ha,

REG = Regional dummy (1=favourable, 0=unfavourable region), Sivagangai district was classified as the unfavourable region in view of its lowest wet season rainfall among all the four districts. The other three districts were classified as favourbale region.

REACH = Dummy for farm location (1=head; 0=tail),

LAB = Labour used for rice cultivation (man-days/ha),

FYM = Farmyard manure for rice (kg/ha),

TANK = Volume of tank water (hacm),

WELL = Volume of well water (hacm),

TTYPE = Tank type (0=PU tank; 1=PWD tank),

NTGN = Nitrogen for rice cultivation (kg/ha) and

WUO = Water users' organisation (0=if absent; 1=if present).

Sine the variable tank type (TTYPE) was not statistically significant, separate production functions were not estimated for PU and PWD tanks. The results of production function indicate that the yield variation between the favourbale and unfavourable regions was highly significant (Table 6). The rice yield in favourable region was, on the average, higher by 475 kg/ha than the unfavourable region. The yield difference between the head and tail reach farms was also highly significant. The head reach farms, on the average, recorded a higher yield of 331.8 kg/ha than the tail reach farms. Supplemental well irrigation was also statistically significant. The marginal productivity of well water was about 9 kg, while that of tank water was only 0.31 kg and it was not statistically significant. This implies that supplemental well irrigation plays a crucial role in stabilising/increasing the rice yield in the tank commands. The non-significance of tank water in affecting rice yield and the positive and significant impact of supplemental well water on rice yield might seemingly be an argument for the promotion of well irrigation in tank commands. However, the actual implication of this result is quite the contrary. The non-significance of tank water in affecting rice yield was due to the equitable supply of tank water to the sample farms in all the tanks since the data collection for the study was done in years of normal rainfall. Further, the difference in total water availability (tank + well water) in such a situation is purely captured by the inequalities in access to well water alone either owned or purchased. Given such a situation, the positive and significant impact of supplemental well irrigation is a beneficial step from the point of view of individual farmer's benefits. Each well owner, as a local monopolist, pumps more water than required in order to maximise his returns. An earlier study by Palanisami and Easter (1991) indicated that profit-maximising level of well water application to be 6 hours per day compared to 4 hours per day actually required by them.

TABLE 6. REGRESSION OF FACTORS AFFECTING RICE YIELD

Sr. No. (1)	Variables (2)	Regression coefficient (3)	t-value (4)	Level of significance (5)
1.	REGDUM	474.87	3.89	0.00***
2.	REACH	331.54	3.12	0.00***
3.	LAB	6.82	7.21	0.00***
4.	FYM	0.015	2.50	0.01**
5.	TANK	0.31	0.183	0.51
6.	WELL	8.96	2.92	0.00***
7.	TTYPE	80.68	0.72	0.47
8.	NTGN	4.61	4.12	0.00***
9.	WUO	477.3	4.30	0.00***
	$R^2 = 0.43$	N = 716	F = 27.46	Significance: F=0.00.

* ** and *** Significant at 10, 5 and 1 per cent level respectively.

Human labour and nitrogen were other important factors that had a significant influence on rice yield. The marginal product of human labour was about 6.25 kg, while that of nitrogen was 5.25 kg. The farms with tanks with water users' organisation have obtained significantly higher yield of about 477 kg more than those with tanks without water users' organisation, due to better water control and management. It was also observed that in tanks with water users' organisations well owners used to give their turn of tank water to other farmers and rely on their groundwater supplies.

Water Market

Water market was not very active in the study years 1992-93 and 1993-94, owing to fairly good rainfall in these years that obviated the need for purchase of supplemental well water by the non-well owners. However, earlier studies in the state had clearly indicated the active role of water markets in low rainfall years (Palanisami and Easter, 1991; Janakarajan, 1993; Shobha, 1990). Buying/selling of water was not observed in more than 90 per cent of the farms in both the PU and PWD tanks. In both the years water sales were noticed only in 5 per cent of PU tanks and in 7 per cent of PWD tanks, while water purchase was observed in 8 per cent of both the PU and PWD tanks. The number of hours of water sales for one rice crop was 56.54 in PU tanks and 60.90 in PWD tanks; while the extent of water purchase was 69.83 hours in PU tanks and 63.92 hours in PWD tanks. The price of water varied from Rs. 10 to Rs. 30 per HP-hour (Palanisami *et al.*, 1997). Inasmuch as 50 per cent of PU farms bought water, the buyers had to part with one-third of their crop produce to the sellers, whereas in PWD tanks only about 14.50 per cent of water buyers had to part with one-third of their crop produce. This again indicates that the tank water scarcity was more pronounced in PU tanks than in PWD tanks because of which a higher percentage of well owners in PU tanks could extract more rent (one-third of crop produce) for groundwater. The average price of water was Rs.11.6 HP-hour in PU tanks, whereas it was only Rs.10.4 per HP-hour in PWD tanks. The share of cost of well water purchased was 19 per cent to the total return from rice cultivation in PU tanks, while it was only 11.60 per cent in PWD tanks. The higher price of well water and the higher share of cost of well water in total revenue of the farmers in PU tanks than in PWD tanks indicate that the water market was less competitive in PU tanks than in PWD tanks. This might be due to higher dependence on purchased well water for successful crop production in PU tanks than in PWD tanks. This reinforces the results of the earlier discussion at tank level, indicating higher tank water scarcity in PU tanks than in PWD tanks.

As the tank water supply decreases, normally the price of well water increases substantially, due to the rise in monopoly power of the well owners, which increases with an increase in the number of water buyers as well as a decline in the number of potential water sellers. When the tank water supply is lower than 25 per cent of the full tank capacity, the water buyers had to pay more than one-third of their crop output, which works out to more than 40 per cent of the net profit from rice production. It was observed that about 9 per cent of the income accruing to the non-well owning farmers is captured by the well owners in PU tanks and it was about 7.5 per cent in PWD tanks. If this is translated in terms of the total number of water buyers in the tank, then it will be about Rs. 313.6/ha with two irrigation and Rs. 1,097.6/ha with seven irrigation in PU tanks, and it will be Rs. 275/ha with two irrigation and Rs. 963/ha with seven irrigation in PWD tanks (Table 7). Considering that about 30 farmers have wells in a typical tank command area which could cover about four hectares per well, the total area supplemented by the water market will be about 120 hectares per tank. Hence, the income of the well owners will be about Rs. 94,080 with five supplemental irrigation and it will be about Rs. 1,31,712 with seven supplemental irrigation in PU tanks. In PWD tanks it will be about Rs. 82,560 and Rs. 1,15,584 with five and seven supplemental well irrigation respectively, thus indicating the private prosperity of well owners in the tank commands. The excess profit earned by the well owners from sale of water to non-well owners adds strength to the argument that the sale of well water in the tank commands should be taxed indirectly through pro-rata electricity tariff. The water users' associations may be empowered with the collection of power tariff on a commission basis. Community wells may be exempted from payment of power tariff.

TABLE 7. WELL OWNERS' PROFIT FROM WATER SALES

Number of well irrigation	Actual cost of well water (Rs./ha)		Total cost based on well owners' price (Rs./ha)		Well owners' profit (Rs./ha)	
	PU	PWD	PU	PWD	PU	PWD
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	34.4	36.8	348	312	313.6	275.2
2	51.6	55.2	522	468	470.4	412.8
3	68.8	73.6	969	624	627.2	550.4
4	86.0	92.0	870	780	784.0	688.0
5	103.2	110.4	1,044	936	940.8	825.6
6	120.4	128.8	1,218	1,092	1,097.6	963.2

Notes: Average duration of irrigation = 15hrs/irrigation/ha;
Actual well water cost (taking into account the fixed and variable costs) was Rs. 18.4/hr in PWD tanks and Rs. 17.2/hr in PU tanks;
Average well owners' price = Rs. 10.4/hr in PWD tanks and Rs. 11.6/hr in PU tanks.

Further, the earlier discussions on overall tank performance revealed that tank performance is negatively affected by the growth of wells, and the well water itself is the private appropriation of community tank water and return seepage from tank irrigated fields. Precisely at this juncture the discussion on conflicting interests of well owners and non-well owners vis-a-vis the sustainability of tank irrigation should take a decisive turn towards the sustainable management of tanks so as to discourage the growth of private wells in tank commands. To ensure this, wherever there is a strong case for the use of supplemental well water for successful harvest, it should be solely through the construction of community wells, which would strengthen the community management of both tank and well water in the tank commands.

VI

CONCLUSIONS

The results of tank level study on well density and tank performance indicate that the increasing number of wells pose a serious threat to the sustainability of tanks as a direct source of irrigation. Strong negative relationship between well density and tank performance adds strength to this argument. In tanks where the well density has exceeded one well per hectare of tank command area, the tanks have become totally defunct. In such cases, the tanks serve indirectly to well owners by recharging their wells at the cost of non-well owners. At best the tanks are serving as percolation ponds in such areas. On the other hand, the farm level study on water management reveals that the total water applied for rice crop in farms irrigated by wells was found to be about 50-100 per cent higher than the water applied in non-well owning farms in both the PU and PWD tanks. The rice productivity was found to show a positive relationship with well water supplementation up to 15 supplemental well watering. Further, the well owners are able to earn substantial income from sale of water, and at times they act as local monopolists due to large number of non-well owners who depend on the well owners. Many times the non-well owners are forced to buy water only from a particular well owner due to the non-availability of water courses from other wells to carry well water even though it is available at cheaper cost. The share of cost of purchased well water ranged from about 15 per cent to one-third of the total cost of cultivation of non-well owners. Therefore, the private well owners are in a distinctly advantageous position though their wells get recharge from common property tank water.

The results from tank level study and the farm level study lead to an interesting debate over the presence and role of wells in the tank commands. While the tank level study points to the negative impact of wells on long-term sustainability of tanks, the farm level study suggests that the presence of wells (and hence well irrigation) in the tank commands could increase the rice yield at least in the short run. Hence, we observe a classic case of the 'tragedy of the commons' in tanks, in the sense that the short-run objective of the private well owners is in conflict with the long-run sustainability of tanks as a common property resource. However, the marginal cost to the individual farmer due to long-term decline in tank performance is lower than the short-run marginal benefit from investment on wells. This gap is further widened due to the existence of local monopoly in water markets, which yields super-normal profits to the well owners, indicating that the benefits of common property resource are more or less captured by the private investments, where the common property is known to be mismanaged. This vicious cycle, where more construction of wells affects the tank management or poor performance of tanks affects well investment, needs to be carefully balanced on the long-run sustainability of tanks. The role of community wells needs to be emphasised in terms of cost of irrigation and equity in groundwater supplies.

These issues apart, there are other arguments that support well irrigation in the tank commands on limited scale, on the following grounds: (a) The wells capture the seepage water from tanks/channels/fields which would have otherwise gone waste, and (b) private investment on wells could, to a large extent, supplement the loss in tank storage due to siltation, the removal of which requires large investment on the part of the community/government. Therefore, the desirability or otherwise of large-scale well irrigation in the tank commands is a complicated issue that needs to take into consideration the wide range of issues including the long-run and short-run objectives of the society and individuals. To get maximum benefits, it is also warranted that tank management be strengthened which will have indirect control over the higher concentration of wells as well as on water markets. Through rotational system of water delivery among sluices, the wells will be getting adequate recharge and tank storage can also be prolonged thus reducing the heavy dependence on wells (Palanisami and Flinn, 1988, 1989). Measures such as community wells and the revival of traditional irrigation institutions will go a long way in sustaining the tank systems, while meeting the farm level demand for supplemental well irrigation in years of poor tank storage.

In addition, the entire water resources within the hydrological boundary of the tanks shall be declared as the common property of the village community as a whole, while empowering the water users' associations to decide the extent and purpose of its use. Even though the PU tanks performed poorly due to higher well density and encroachment, it is heartening to note that the farmers' particpation in tank maintenance has significant positive impact on overall tank performance in both the PU and PWD tanks. Further, the presence of water users' organisation has a significant positive effect on rice yield at the farm level, due to improved water management. These two results lend credence to the argument for increased role of people's participation in tank management in order to minimise the conflicts between tanks and wells.

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NOTES

1. Resource mobilisation includes tangible economic benefits obtained from tank usufructs such as sale of trees raised/naturally growing in the tank bunds and the water spread area, sale of fishes, duck rearing, sale of silt and revenue collected for permitting the cattle grazing in tank water spread and/or command area after the harvest.

2. By real performance we mean the actual performance of tanks excluding the contribution of wells (positive or negative) to the overall observed tank performance measured, which is usually measured as the ratio between actual area irrigated by the tank to the total registered command area of the tank.

3. Janakarajan (1993) observed strong negative relationship between well density and the effectiveness of traditional irrigation institutions. He further observed that the traditional irrigation institutions are effective in those tanks where the well density is typically below 0.40 wells per ha. In the present study, the threshold number of wells for PU and PWD tanks is 0.42 and 0.35 respectively. Hence, it is reasonable to assume that for those tanks having well density above these levels, the wells were assumed to be negatively contributing for tank performance.

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