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I. Introduction

Tamil Nadu accounts for about two per cent of land and water resources available at the national level, but it needs to cater the needs of eight per cent of Indian population. In coming years, when 1200 persons will share 1 million cubic meter of water at the national level and in Tamil Nadu it will be 2000 persons per year. An important problem in creating new irrigation potential is the limited financial resources coupled with improper utilization of existing minor irrigation sources such as tanks. Using 39,202 tanks in Tamil Nadu, potential area to be irrigated by tank would be around 900,000 ha, loss due to defunt tanks will be about 50,000 ha, and hence, area that could be irrigated will be about 850,000 ha, but actual area irrigated is around 670,000 ha. Therefore the estimated area lost due to the mismanagement will be about 180,000 ha (Palanisami, 2001).

Hence, improving the performance of tanks in Tamil Nadu seems to be a viable and the best available option. The tanks have wider geographical distribution and hence any investment to improve and restore them would reach vast majority of the people. More over, tank irrigation is the most desirable system of water harvesting from the ecological and sustainable points of view.

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Normally in the wet season (October -December), rainfall accounts for about 20% of water needs of rice, while the remaining 80% is met from tank and ground water irrigation. Unfortunately, the performance of the tanks over the period become poor due to inadequate operation and maintenance, erratic rainfall, rapid development of ground water resources, concentration on canal irrigation system, heavy siltation in tank water spread, feeder channels and encroachment in foreshore area of the tanks.

Given the importance of the tank irrigation in Tamil Nadu, the government has started several programmes to help strengthen tank irrigation. These programmes intended primarily: (i) to provide major repairs and improve tank performance (ii) to increase irrigation potential by constructing new tanks and (iii) to improve existing tank structures. In spite of these attempts, there is a big gap in reaching out the expected outcome. Again all these attempts through small improvements had been made in comparatively small number of tanks and not covering the state as a whole. Normally government has attempted tank rehabilitation through small improvements. However, no big attempt has been made until European Economic Committee (EEC) came forward to modernize 649 tanks in Tamil Nadu during 1984-05 to 1994-95. In this context, tank modernization is the process by which the water in existing tanks is used more efficiently through improved water storage, distribution and on-farm water use. The aim is to increase food production and rural incomes by achieving higher cropping intensity through improved water management and reduced water losses.

EEC Tanks modernization programme

This programme was implemented during 1984-85 to 1994-95, with financial aid from European Economic Community (EEC). In the first phase (1984-91), a total of 150 non-system tanks with a command area of 100-200 ha were selected for modernization with a financial outlay of Rs. 4,500 lakhs. In the second phase (1989-

1995), an additional 230 tanks were included and in the same period, considered as phase II extension 269 tanks were also included at a financial outlay of Rs. 5,000 lakhs. The approximate cost per hectare was Rs. 21,000. The project was expected to save about 20% of water over the present use, thus permitting the expansion of cultivation by about 9,000 ha (Government of Tamil Nadu, 1986).

To select tanks for modernization, the PWD used the following criteria.

1. The command area of the tanks should be between 100-200 ha
2. The number of tank fillings should be less than two
3. The command area should be 90-95% cultivated
4. The tanks should be non system tanks
5. The tanks should be easily accessible.

It is believed that it has improved the water use efficiency of tank irrigation systems and the experience will be useful in the future tank modernization programmes by the government departments and funding agencies. Subsequently, several proposals from state government and other institutions have been sent to various funding agencies indicating that tank modernization is important in reviving the tank irrigation. But no study has been conducted to assess its impact on tank economy. Hence it is important to study the impact of EEC tank modernization project which will give good insight to policy makers, researchers and field workers.

Research Hypotheses

1. EEC tank project was effective for the improvement of tank performance.
2. Tank performance is better where participatory approach in tank management was adopted.
3. Water users association is active where socio-economic conditions are favorable.
4. Stable water supply is a detrimental factor for better tank performance.

Objectives of the study

1. To study the impact of EEC modernized tanks with relation to socio-economic condition of farmers.
2. To compare modernized tanks with non-modernized tanks with the relevance to their performance.

II Methodology

EEC has modernized 649 tanks spread over 17 districts of Tamil Nadu. This section deals with the procedure followed to identify study area and tanks.

1. Selection of study area

It is decided to conduct the study in tank intensive districts as tank irrigation is more important in these districts. In Tamil Nadu two regions are considered as tank intensive viz., North region, comprising of Vellore, Tiruvannamalai, Kanjeepuram and Villupuram districts and Southern region, comprising of Madurai, Virdhunagar, Sivagangai, Ramanathapuram and Pudukottai districts. Southern districts had 40% share in total modernized tanks (267 out of 649 tanks). Hence, it is decided to study southern district of Tamil Nadu *viz*., Madurai, Ramanathapuram, Virudhunagar and Sivagangai.

Commonly, the tanks were constructed in cascade, so that surplus water from one tank will go to the next tank in the cascade or chain. Hence, the tanks located in the head of the chain has more favorable water supply than other tanks in the chain. So it is decided to identify all the modernized tanks with its chain and its location in the districts. Materials and maps were collected from PWD records and block-level administrative offices. Personal visit was also made to have discussions with responsible PWD engineers.

Using this material, we plotted all the modernized tanks in chain, in order to know the exact location of modernized tanks in the chain (List of identified chains is given in Appendix 1). Then, we selected tanks which were located in the head of the chain in order to eliminate factor of water supply, the crucial factor to determine tank performance. Considering short period of time for the study, six tanks from Madurai, Virudhunagar and Ramanathapuram district were selected, and in Sivagangai alone 7 tanks as it has more number of tanks under modernization than other districts. Totally 25 EEC modernized tanks were selected for the study. To compare EEC tank programme, with the non modernized tanks, tanks located close to the selected EEC tanks with similar characteristics had been selected (6 each from 3 districts and 7 from 1 district). Thus, the total sample size for the study was 50 tanks (25 EEC and 25 Non-EEC tanks).

Period of study

This study was conducted during October-December, 2006.

Method of survey and data collection

Both primary and secondary data were collected for this study. Two field staff were employed for this purpose. Secondary data like total *ayacut* (command) area and other hydrological details were collected from PWD official memoirs. Revenue related details were also collected from village administrative officer. Primary data was collected through pre-tested interview schedule, paying personal visits to the tank villages.

Methods and tools of analysis

All the collected data were entered in excel work book. Percentage analysis, average, correlation, t test, regression and equity analysis were used to analyze the collected data. Analyzed data are discussed in the following sections.

Description of the variable used in this study

Tank performance: It is the percentage of the total area cultivated to the total command area of the tank in a particular year.

Tank performance (%) = (Actual area cultivated /Total command area) x 100

However, the total performance should be redefined taking into account the intensity of wells, as in several tanks the role of wells in stabilizing the tank irrigated area is more significant.

Filling pattern: How many times tank get filled up during the tank irrigation season.

Water availability: Number of days of water availability in the tank in the crop season.

Encroachment: It is the percentage of the tank foreshore and tank water-spread area encroached by others in a particular tank.

Siltation: It is the percentage of the tank water spread area silted up.

Presence of water users association: It is the presence of either formal or informal water users association in a tank. It is referred as 1 if present and 0 otherwise.

Presence of *Neerkatti*: Presence of common waterman or *Neerkatti* in a particular tank. It is referred as 1 if present and 0 otherwise.

Participation of farmers: Farmers contribution to tank maintenance as labour or money or both. It is referred as 1 if yes and 0 otherwise.

Government support: Availability of government support in tank management. It is referred as 1 if available and 0 otherwise.

Maintenance of tanks: Maintenance of the tanks by the PWD or *panchayat* or farmers. If it is good, then a score of 2 is assigned and if not, a score of 1 is assigned.

Farm income: Gross income from crop cultivation in the crop season.

Water distribution: It refers the equity in water distribution between head and tail farms. It is referred as 1 if yes and 0 otherwise.

Adoption of water management practices: It refers the adoption of water management practices by the farmers. It is referred as 1 if yes and 0 otherwise.

Employment opportunity: No. of man-days available for employment in a particular year in tank-based agriculture.

Cooperation among farmers: It refers the cooperation among the farmers in sharing the available tank water. It is referred as 1 if yes and 0 otherwise.

Well density: No. of wells per ha of the tank command area.

Caste composition: No. of caste groups that depend on the tank for their livelihood

Effectiveness of WUA: It is measured in terms of their participation in tank water allocation decisions, disputes settlement and collection money for tank management.

III Results and discussion

Collected tank data were analyzed and are discussed below.

1. General characteristics of EEC modernized tanks

Tanks have been influenced by three important factors *viz*., hydrological factor, socio-economic behavior of farmers and administrative factors.

Table 1 shows that average *ayacut* (command) area of these tanks was 120 ha and it has been distributed among 357 farmers. Thus, one farmer would have merely 0.34 ha of land to cultivate and earn for his family. Average family size of sample village was 5.2 ha. These tanks had only one filling per year, but they had 1.36 fillings 10 year before. Farmers of these tanks felt that 1.5 filling is needed to have successful crop harvest. One filling can supply water for 55 days. If they have 1.5 filling per season, available water supply will goes to 75 to 85 days, which will manage to get some good harvest. Here, again 36.2% of tank storage capacity has been reduced due to siltation.

So, total dependence of paddy cultivation on tank water currently leads to miserable condition. The tanks get less than two month storage in 5 out of 10 years, commonly causing crop failure and yield reduction. In order to manage or escape

Table 1. General Characteristics of EEC Modernized Tanks (n = 25)

Villages	Tank performance (%)	No. of HH in *Ayacut*	Change in						No of wells		
			Filling pattern (No)		Water Availability (days)		Siltation (%)				
			10 yr before	Present	10 yr before	Present	10 yr before	Present	70's	80's	90's
Sowdarpatti	80.23	800	1.75	1	120	90	20	40	20	20	25
Saptur	82.12	700	2	1	90	50	10	40	20	30	30
Kudisery	79.45	1500	1.75	1	120	90	20	30	10	15	25
Thambipatti	84.50	150	1.50		60	40	10	25	15	25	25
Kottaiyur	82.21	400	2	1	65	40	10	40	25	25	25
Sundrarajapuram	83.12	300	2.5	1	60	40	10	25	25	25	25
Srivilliputtur	90.23	800	2.5	1.5	65	40	15	25	30	50	50
Vellur	86.15	300	2	1.5	50	30	15	40	0	0	5
Kunnathur	82.90	250	1	1	90	70	25	40	7	7	11
Sambakulam	92.15	200	2	1	150	35	20	50	13	15	15
Adanoor	81.52	100	1	0.75	50	30	30	60	5	5	5
Chitrakudi	81.30	250	2	1	190	70	20	30	4	4	4
Arasani	84.25	80	2	1	120	70	20	30	0	0	0
Theriruveli	80.50	650	1.5	1	40	60	35	25	0	3	4
Oriyur	72.25	500	1	1	100	75	35	30	5	5	4
Nallakulam	79.74	70	1	1	90	70	25	40	4	4	4
Aralikottai	80.13	150	2.5	1	60	40	10	25	5	5	5
Taraikudi	83.58	260	2	1.5	80	50	30	50	2	2	2
Mosukudi	84.10	150	1	1	30	40	40	30	0	0	0
Velankudi	85.25	220	2	1	90	60	25	45	3	3	3
Melrangiyam	84.23	40	1	1	30	50	50	60	0	0	0
Algan sirukudi	88.50	350	1	1	90	70	30	50	0	0	0
Nerkuppai	77.75	350	1	1	90	70	20	40	0	0	0
Padamathur	72.00	360	1	1	120	90	25	35	0	0	0
sathamangalm	70.28	300	1	1	100	80	24	40	0	0	0

HH : Household

from this strange situation, farmers need to provide supplemental irrigation using well water. Density of the well was also very less viz., one well will cater to the needs of 33 farmers or one well needs to give supplemental irrigation for 11 ha which is very difficult under present situations. Since, wells depends on tank storage for recharge, poor tank supply also affects the well recharge. Normally, to irrigate one hectare, about 20 hours of pumping is required and wells will not have sufficient water to pump continuously. Even if ground water is available, Rs. 700-1200 is needed to pay for the water to irrigate one hectare of land. As most of the farmers are belonging to small and marginal category, they could not afford this cost even if water is available.

Most of the farmers are looking for alternative opportunities to alienate their deprived conditions. Livestock rearing was a viable option as most of the farmers have started practicing it. If the farmers could adopt some of the water management techniques like alternative wetting and drying, avoidance of field to field irrigation, cultivation of short duration varieties it is possible to get successful crop with the available tank and well water.

2. General characteristics of Non-EEC tanks

It could be interpreted from Table 2 that average *ayacut* area of these Non-EEC tanks is 207 ha and 414 farmers shared these lands. Thus, one farmer would have 0.5 ha of land. Hence, one farmer depended for his livelihood mostly less than 1 ha of land. Tank water supply was 109 days with the average filling of 1.86 times per year 10 years before, but decreased to 63 days, resulting in crop failure or poor harvest.

Non-EEC tanks could supply water for 63 days and EEC tanks could supply for 55 days, but the difference is statistically not significant. Location of the tanks in the chain might have influenced the tank filling and supply. Number of days supplied by extra one week by Non-EEC tanks will not have any significant effects, as these

Table 2. General Characteristics of Non-EEC Tanks (n = 25)

Villages	Tank perfor mance (%)	No. of HH in *Ayacut*	Change in						No of the wells		
			Filling pattern (No)		Water Availability (days)		Siltation (%)				
			10 yr before	Present	10 yr before	Present	10 yr before	Present	70's	80's	90's
Poovanthi	81..12	1000	2	1.5	120	20	30	40	30	35	75
Nilaiyur	80.25	200	2	1	120	55	25	50	5	10	11
Eriyur	77.56	800	1	1	90	60	20	30	15	15	15
Mayaleri	73.50	150	1.5	1.0	120	60	20	40	4	6	6
Kambikudi	79.20	570	2	1	140	40	20	50	20	20	30
Sikkial	81.25	2000	2	1	90	50	10	40	15	10	3
Sulvarpatti	75.23	500	1	1	45	30	25	50	10	15	30
A. Pudupatti	79.74	400	2	1	50	30	10	25	10	25	25
Ayardharmam	82.00	150	1.5	2.5	60	35	20	50	10	10	15
Piramanur	83.25	970	1.5	2.5	80	35	20	50	50	70	93
Theni	82.30	170	1	1	50	50	40	50	-	-	-
Koovalapuram	79.00	250	3	1	180	50	15	50	10	10	20
Kilankulam	84.52	127	1.5	1	120	60	20	50	0	0	0
Ponnampatti	79.36	200	1	1	120	60	220	50	0	5	8
Watrap	78.35	500	2	1.5	120	50	30	40	100	110	140
Silaimalkipatti	87.12	312	3	1	150	80	20	50	10	30	35
Jariusilampatti	78.58	150	2.5	1	100	60	10	60	-	5	20
Madapuram	83.88	700	1	1	90	60	20	50	-	15	20
Thuthai	75.23	60	1	1	100	80	10	20	-	-	10
Thevathanagudi	75.14	175	2	1	90	60	40	50	-	4	8
Kalangapuli	90.00	15	2	1	90	60	30	40	-	-	-
T. Kallikulum	83.11	300	3	1	150	30	25	40	-	-	2
Marathai	81.55	500	3	2	120	80	60	40	-	-	2
VKPM	85.23	110	1	0.5	70	40	50	75	-	-	2
Sekhactidal	80.12	60	3	1.1	180	60	15	30	-	-	-

HH : House hold

tanks were located in the same rainfall domain. Decreases in the duration of tank water supply during the last 10 years are, on average, 27 days in the EEC tanks and 46 days in the Non-EEC tanks. Also, in the case of siltation to total capacity, Non-EEC tanks had 20%, but the EEC tank has only 13%. Thus, it could be concluded that EEC works might have influenced positively to stabilize water availability in the tanks over the period of time. Even though EEC works were not for full scale de-silting, some of the catchments treatment might have influenced the pattern of silting after modernization.

Approximately 23 wells were to cater to the needs of 414 farmers in the *ayacut*, i.e. 1 well for every 9.09 ha of land. Earlier (20 years back) all these tanks cultivated 2 rice crops per year, now they cultivated only one rice crop. If tank has some surplus water or utilizing available soil moisture in the paddy fields after harvest, farmers used to cultivate black gram or chilies or groundnut with three month duration.

3. Participation of WUA and farmers in EEC tank villages

It could be concluded from Table 3 that, 96% of selected EC tanks maintained by PWD and only 4% by the *Panchayat* Union (PU). It is because of that EEC adopted the criteria where tanks with 100-200 acres of tank command area only should be selected. Usually all the *Panchayat* Union tanks have less than 100 acres of command area and this could be the possible reason for such an outcome.

In the case of WUA (water user's association), 28% of villages have such an organization, the remaining 72% of villages did not have water user association. Out of 28% of WUA, 86% of WUA have received farmer's active participation. The remaining 14% of WUA did not get farmer's participation as expected. This is mainly because, during the implementation of EEC modernization programs, it is mandatory to have WUA at the tank level. Hence, WUA in most of the villages, were newly formed merely because of EEC norms. However, once modernization work

able 3. EEC Tank Characteristics

Tank village Name	Presence of WUA	Presence of *Neerkatti*	No of caste in *Ayacut*	Intervention if any (other than EEC)	Classification of households in villages (%)			
					Farming	Non farming	Landless Ag. Lab	Landless Non Ag. Lab
Sowdarpatti	Yes	Yes	4	No	60	20	20	0
Saptur	No	Yes	3	No	83	7	10	0
Kudisery	Yes	Yes	5	No	90	0	10	0
Thambipatti	Yes	Yes	4	1980	66	17	17	0
Kottaiyur	No	Yes	5	No	70	15	15	0
Sundrarajapuram	No	Yes	3	1984	80	0	20	0
Srivilliputtur	Yes	Yes	5	2001	40	40	10	10
Vellur	No	Yes	5	No	70	10	10	10
Kunnathur	No	Yes	4	2004.	40	0	60	0
Sambakulam	No	No	3	No	60	20	20	0
Adanoor*	No	No	1	No	100	0	0	0
Chitrakudi	No	No	6	No	75	0	25	0
Arasani	No	No	3	2001	50	25	25	0
Theriruveli	Yes	Yes	5	2004	30	10	30	30
Oriyur	No	Yes	5	2006	75	0	25	0
Thalirmarukur	No	Yes	5	2006	80	0	10	0
Nallakulam	No	No	4	2003	90	0	10	0
Aralikottai	Yes	Yes	5	No	75	10	15	0
Taraikudi	No	No	3	No	80	0	20	0
.Mosukudi	Yes	Yes	5	No	100	0	0	0
Velankudi	No	Yes	5	2003	80	0	20	0
.Melrangiyam	No	No	2	No	80	0	20	0
Algan sirukudi	No	No	5	No	50	0	25	25
Nerkuppai	No	Yes	5	No	80	0	10	10
Padamathur	No	Yes	4	2001	80	0	10	10

* PU Tank

was completed, WUA was inactive, because of poor cooperation and commitment among themselves.

In the case of *Neerkatti* (waterman), 68% of the tank village had waterman. Only 32% of villages did not have. When compared to the percentage of WUA it was somewhat good number. It is mainly because; appointing water man was traditional practice. Particular family from particular community in every village was responsible for this work and is usually called as *Madayan Thotti*, *Madayar*, *Neepachi*, etc. This process is by hereditary and not by election or selection. These traditional institutions still play a major role particularly when the tank receives normal or just below normal rainfall. This could be the possible reason for the seemingly success of these institutions in the water distribution.

Still 32% of tank village did not have waterman. It is mainly because of shrinking gap between upper caste and lower caste. Usually waterman belongs to scheduled caste, small in population in every village and without any landholding. Now, because of enforcement of un-touchability law where the government is showing keen interest to provide equal rights to everybody irrespective of communities they belong. To improve living standard of SC people, government has announced number of welfare schemes. Hence, most of them had studied in the schools and prefer non agricultural jobs. In the meantime upper caste people tend to migrate out after selling the lands to other farmers or laborers who earlier worked in the farms. Hence, in the tank villages, the waterman community has slowly started disappearing.

4. Farmer's participation and presence of WUA in the non-EEC tanks

Table 4 reveals that 80% of the selected study tanks were managed by PWD, the remaining 20% by *Panchayat* Unions. Only 36% of the tank villages have water

Table 4. Non-EEC Tank Characteristics

Tank village name	Presence of WUA	Presence of *Neerkatti*	No. of caste in *Ayacut*	Intervention if any	Classification of households in the villages			
					Farming	Non farming	Landless Ag Lab	Landless Non Ag Lab
Poovanthi	Yes	No	2	Yes	50.00	17.50	17.50	15.00
Nilaiyur	No	Yes	2	No	50.00	25.00	12.50	12.50
Eriyur	No	No	4	No	100.0	0.00	0.00	0.00
Mayaleri	No	Yes	6	Yes	44.42	14.63	24.39	16.26
Kambikudi	No	Yes	5	Yes	40.00	20.00	24.00	16.00
Sikkial	Yes	Yes	5	SC	50.00	3.33	40.00	6.64
Sulvarpatti	No	No	4	-	33.34	33.34	16.66	16.66
A. Pudupatti	No	Yes	5		60.00	20.00	20.00	0.00
Ayardharmam	No	Yes	3		62.50	12.50	25.00	0.00
Piramanur	Yes	Yes	4	No	77.28	6.81	6.81	9.10
Theni	No	No	3	-	71.42	7.15	7.15	14.28
Koovalapuram	Yes	Yes	5		26.66	40.00	16.67	16.67
Kilankulam*	Yes	Yes	1		27.77	40.74	12.96	18.52
Ponnampatti	No	No	3		80.00	0.00	20.00	0.00
Watrap	Yes	Yes	5	-	42.85	35.72	14.28	7.15
Silaimalkipatti*	Yes	No	8	Yes	30.00	30.00	20.00	20.00
Jariusilampatti*	No	Yes	4	No	75.00	0.00	25.00	0.00
Madapuram	No	Yes	4	-	55.56	11.11	22.22	11.11
Thuthai*	No	No	3	-	55.56	16.66	13.89	13.89
Thevathanagudi	No	Yes	5	-	66.67	11.11	11.11	11.11
Kalangapuli*	No	No	2	-	72.24	13.88	13.88	0.00
T. Kallikulum	Yes	No	2	-	69.50	0.00	12.20	18.50
Marathai	No	Yes	4	Yes	71.42	7.15	14.28	7.15
VKPM	Yes	Yes	5	-	61.90	9.52	23.80	4.78
Sekhactidal*	No	Yes	4	-	68.26	2.34	5.88	23.52

* PU tanks

user's association. Out of 36% of the tank water user's association, farmer's participation was observed to be good among 44% of water user's associations.

When compared to EEC tanks, there is no compulsion for Non-EEC tanks to have WUA. In spite of this, 36% of tank villages have WUA. Possibly due to several government programmes such as VLSS (Village level self sufficient scheme) popularly called *Namukku Namae Thittam* (we do it for ourselves), in that program, there is a provision, if farmers are ready to contribute Rs. 25 for any common work, government would contribute Rs. 75. Provided the village should have people's organization whether elected or selected. In order to utilize this scheme some village leaders out of their own interest came forward to initiate and form such an organization. This could be understandable that the entire village which has WUA made some good intervention in the tank management also.

Regarding *Neerkatti*, appointing water man was traditional. Particular family from particular community in every village was responsible for this work and is usually called as *Madayan Thotti, Madayar, Neepachi* etc. These traditional institutions still play major role particularly when the tank receives normal or just below normal rainfall. This could be possible reason for the seemingly success of these institutions.

Still 38% of tank village did not have waterman because of shrinking gap between upper caste and lower caste groups as mentioned above.

5. Social forestry in the tanks

The social forestry project was launched in 1981 with Swedish International Development Agency's (SIDA) assistance in Tamil Nadu. The project contemplated a massive afforestration programme to ensure a sustained supply of fuel wood, bamboo, small timber and other minor forest produce to satisfy the local needs. Mostly *Acacia Nilotica* was recommended and cultivated inside the water spread area of the tanks. After few years, complaints came from user groups stating that it

has disturbed their access to the tank maintenance and also reduced water storage capacity. After almost 25 years later, the social forestry has been discouraged in the tank beds. However, the *Prosophis Juliflora* automatically replaced its place more vigorously. Now, the farmers feel that *Prosophis* will be the major threat to tank management, as these trees have no timber value like *Acacia* and *Prosophis* also occupied the supply channels and cultivated lands.

Table 5 reveals that 92% of the EEC tanks had serious the *Prosophis* problem while 88% of the Non-EEC tanks had. Earlier there was need for fuel wood, hence, the village people used to come and cut *Prosophis* trees. So the equilibrium has been managed somehow. But now, even though the supply of wood is increasing, demand for fuel wood is decreasing due to the increasing availability of other fuel source like kerosene and gas. This leads to proliferous growth of *Prosophis* and even occupied entire command area and tank bunds in most of the tanks.

Many farmers feel that the *Prosophis* will affect the crop fields, as it is easily grown during scarcity periods, as farmers often fallow the lands. It is seen that it costs about Rs 7000 per acre to clean the *Prosophis* trees which is almost equal to the cost of cultivation of rice.

Table 5. Degree of *Prosophis* Infestation in the Tanks

Tanks	Very serious		Serious		Not so serious	
	No	%	No	%	No	%
EEC tanks	20	80	3	12	2	8
Non-EEC Tanks	16	64	6	24	3	12

Table 6. Value of the Land Based on Their Location in the Tank Command

Location	EEC Tanks	Non-EEC Tanks
Head (Rs/ac)	74,600	80,480
Middle (Rs/ac)	61,400	62,600
Tail (Rs/ac)	53,520	56,400

Table 7. Migration Behaviour of Farmers in the Tank Command

Tanks	Total No of HH	Average No of mandays Available/Year	Migrated Household	Percentage to the Total
EEC	14,798	120	855	5.79
Non-EEC	11,423	100	882	7.72

Table 8. Labour Wage Rate in the Tank Command Area

Tanks	Agriculture		Non agriculture		Differences	
	Men (Rs/day)	Women (Rs/day)	Men (Rs/day)	Women (Rs/day)	Men (Rs/day)	Women (Rs/day)
EEC	80.80	45	104	60.71	23.20	15.71
Non-EEC	77.80	41.60	111	92.50	33.20	14.80

6. Land value in the study villages

Table 6 shows that both in EEC and Non-EEC tanks *ayacut*, lands located close to the tank bed or sluice fetched higher price. Lands located in head region of the tanks fetched 28% higher than lands located in tail for EEC tanks, and head to tail difference in land value was 30% for Non-EEC tanks.

Availability of water and access to the tank water are important factors in deciding the price of lands in the command. Also the tanks close to the urban areas as well as roads always have a higher land value.

7. Migration behaviour of villagers in the tank villages

It could be concluded from Table 7 that 5.8% of people of EEC tanks and 7.8% of Non-EEC tanks migrated to nearby cities. This has happened mainly because of non-availability of assured employment opportunities throughout the year. The employment was ranging from 80-120 days per year in EEC tanks compared to 75-100 days in Non-EEC tanks. Education also encouraged them to move out. For

example, those educated upto X^{th} standard onwards had the tendency to move out to the cities, as they could easily find alternative employment. Government's education programme and ration shops in the villages further helped the villagers to educate their children upto elementary school level and send them to nearby towns for jobs.

8. Wage rate of labour in the tank villages

Farmers often felt that demand for agricultural labour has increased, and thereby the wage rate was also high. Also, due to out migration, labour scarcity is felt in most of the villages during peak crop season. As a follow up, farm machineries have been used mainly in field preparation and harvest.

The average wages for agriculture works were Rs. 81 per day for man and Rs. 45 per day for woman at the EEC tanks, while they were Rs. 78 and Rs. 42 for man and woman, respectively, at the Non-EEC tanks (Table 8). The differences between the EEC and non-EEC tanks are not significant.

Interestingly, for non-agricultural jobs, man would get Rs. 104 per day; women would get Rs. 61 per day. So, the difference of wage rate between agricultural and non-agricultural works would be Rs. 23 per day and Rs. 16 per day for men and women, respectively, in EEC tank area. These were Rs. 32 and Rs. 15 for man and women, respectively, in non-EEC tanks. The differences between EEC and non-EEC tanks are statistically significant. In several tanks, farmers had reported that future agriculture will be much affected due to labour shortage and high wage rate.

9. Roles of water user association in the tank management

Many studies confirmed that farmers' collective action will lead to better performance of common resources like tanks (Sakurai and Palanisami, 2001). Earlier, *kudimaramathu*, tank maintenance by people themselves, was sincerely practiced, in

which *maramathu* means ‘maintain’ and *kudi* means ‘people’. But this practice has gradually disappeared over the period of time. This is the reason why the informal WUA also disappeared over the years. Hence, it is important to know the present roles of water users association in the tank management. As such 15 different types of work expected to be carried out by these association were identified (Table 9).

Table 9 has clearly indicated that EEC tanks gave importance to only 5 roles among the 15 roles to be played by the association. All association members opined that appointing *Neerpachi* (waterman) and managing him are the most important role, followed by mobilizing farmers for doing common works (86%), supply channel cleaning (71%), and sluice repair and maintenance (71%).

As such, the WUAs had played no role in regularizing fish production, catchment area cleaning and removing encroachment, and control well water price. Due to inadequate tank storage, fish auction could not be done and due to conflicts with the encroachers the association could not make any impact in removing the encroachments. WUAs could not involve in other issues like control the well water price as they could not get full cooperation from well owners.

In the case of Non-EEC tanks, WUAs only showed interest in appointing *Neerpachi* (100%). They did not show much interest in other functions. This may be mainly due to lack of awareness about the importance of tank management. In EEC tanks they had chances to discuss about these issues with EEC officials but in Non-EEC tanks there was no such person to motivate them to participate in tank management. Recent cast and politics based groups are gaining strength and the role of WUAs is much limited due to in fights.

10. Roles of *Neerkatti* in tank management

Neerkattis are almost working as water managers in the tank system. Even though they are not technically qualified, they could judge by experience available tank water and

Table 9. Role of Water User's Associations

S.No.	Criteria	EEC Tanks (n =25)						Non-EEC Tanks (n=25)					
		Normal year		Drought Year		Failure year		Normal year		Drought year		Failure year	
		No	%	No	%	No	%	No	%	No	%	No	%
1.	Supply channel cleaning	5	71	2	29	1	14	2	23	2	23	0	0
2.	Tank bed management	6	86	2	29	2	29	0	0	0	0	0	0
3.	Removing weeds in water spread area	4	57	1	14	0	0	2	22	1	11	1	11
4.	Equal water distribution	4	57	4	57	1	14	1	11	1	11	0	0
5.	Sluice repair and maintenance	5	71	3	43	1	14	2	22	1	11	1	11
6.	Approach government to dig community well	3	42	1	14	1	14	2	22	2	22	1	11
7.	Regular fish production and leasing	0	0	1	14	0	0	0	0	0	0	0	0
8.	Collect common maintenance fund	2	21	4	57	1	14	1	11	1	11	1	11
9.	Appoint common *Neerpachi*	7	100	7	100	2	14	1	11	1	11	1	11
10.	Control well water price	0	0	1	14	0	0.	0	0	0	0	0	0
11.	Encourage crop diversification	1	14	2	29	1	14	1	11	0	0	0	0
12.	Catchment area cleaning	0	0	0	0	0	0	0	0	0	0	0	0
13.	Approach government for funding	6	86	4	57	4	57	2	22	2	22	1	11
14.	Solve dispute between farmers	6	86	6	86	4	57	2	22	2	22	1	11
15.	Mobilize farmers for common work	6	86	2	29	4	57	2	22	4	44	1	11

timing and amount of water release from the sluice very well. The entire water user's association felt that the role of *Neerkatti* in tank is inevitable. As such we have identified 8 roles expected to be carried out by the *Neerkattis*. In normal rainfall year, main role of *Neerkatti* in EEC tanks would be to open and close the sluice in time (58%), maintenance of tank bed, sluice maintenance and organize farmers for common works. *Neerkatti* did not irrigate farmer's fields in normal years, but 47% of *Neerkatti* were assigned with the role of irrigating farmers' fields during the water shortage periods. This arrangement avoided the conflicts among the farmers.

In Non-EEC tanks also *Neerkattis* executed the work viz. opening and closing the sluices in time (100%), ensure the equal distribution of water (67%), organize villagers during emergency (60%).

The predominant role of *Neerkatti* was therefore to ensure equal distribution of available tank water to all. In normal years, it was not a problem. But, when tank filling was short of expected supply, then *Neerkatti* had a crucial role to play as per the direction of WUAs. Usually there were two way of regularizing water supply by *Neerkatti* viz., i) '*Murai Pasanam'* i.e. to irrigate the particular field at regular intervals where the *ayacut* area was divided in to 10 *pungus* (share). One *pungu* was about 63 acres. Water was rotated among these *pungus*. ii) 'Oru madai pachal' i.e., to keep the lowest sluice open and to close the remaining sluices if the tank has more than one sluice. Using the water released from one sluice, *Neerkatti* could equally distribute water to the all the farmers.

It is concluded that there is no significant difference in the roles of *Neerkatti* between the EEC and Non-EEC tanks.

11. Coping mechanism of farmers during water scarcity

The study indicated that 5 out of 10 year's tank would fail to supply enough water. Water availability in the tank was also getting decreased over the periods. Erratic rainfall and poor run off created uncertainties in tank irrigation system. Hence, it is important to

study the role of farmer's collective action to mitigate water scarcity. Data was collected about the strategies and are presented in Table 10. It could be observed from Table 10 that irrespective of EEC and Non-EEC tanks, 96% of the farmers had skipped the tank cultivation and attended the labour work (96%), followed by livestock rearing (68%). About 92% of the farmers opined that they reduced cultivation area, only 27% of farmers opted for water hiring, as this study showed that one well catering to the needs of 11 ha of land was difficult. About 48% of the farmers said that they would opt for less-water-consuming crops or rice varieties. During the survey it has been noted that most predominant paddy variety was ADT 39 whereas it was IR 20 before. Farmers preferred ADT 39 over IR 20 merely because ADT 39 required irrigation two times less than IR 20. Some farmers also opted for fodder cultivation to grow milch animal. Even though crop diversification was advocated, it was not widely practiced yet, as many farmers felt that cultivation of other crops not familiar to them was difficult, besides other issues like marketing etc.

12. Threats to the tank irrigation

Numbers of threats for poor performance of irrigation tanks have been identified. Collected data was analyzed and presented in Table 11.

Tanks were considered as community resource in earlier days, and every villager was aware of the importance of the tank system. It not only served for farmers but also improved the entire village economy and maintaining ecological balance.

It could be observed from Table 11 that irrespective of EEC and Non-EEC tanks, 96% of farmers opined that erratic rainfall would be the main threat, followed by heavy siltation (92%), *Prosophis* (weed) growth in water spread area and supply channel, and poor participation in management activities from farmers and government (80% each).

Table 10. Coping Strategies of Farmer during Water Shortage Period

S.No.	Strategies	EEC Tanks				Non-EEC Tanks			
		Drought year		Failure year		Drought year		Failure year	
		No	%	No	%	No	%	No	%
1.	Reducing crop cultivating area	23	92	23	92	25	100	23	92
2.	Water hiring	7	28	5	20	6	24	2	8
3.	Cultivate less water consuming crops	12	48	6	24	6	24	7	28
4.	Skip the cultivation for the season	24	96	25	100	22	88	24	96
5.	Provide supplement irrigation from own well	14	56	7	28	12	48	5	20
6.	Livestock rearing	17	68	16	64	18	72	12	48
7.	Do the labour work	24	96	24	96	23	92	24	96
8.	Other								

Table 11. Threats to Tank Irrigation

Type of tanks	1		2		3		4		5		6		7		8		9		10	
	No	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**
EEC Tanks	14	56	9	36	23	92	23	92	6	24	18	72	16	64	12	48	24	96		
Non-EEC Tanks	14	56	9	36	24	96	21	84	5	20	20	80	15	60	2	48	24	96		

1. Encroachment in catchment area
2. Well failure
3. Erratic rainfall
4. Heavy siltation
5. Conversion of tanks into percolation ponds
6. Poor participation from farmers and government
7. Migration of farmers and farm laboures to cities
8. Urbanization and tank defunct
9. *Prosophis* growth
10. Others

It is understandable that erratic rainfall is the main threat as tanks had failed to store and supply enough water in 5 out of 10 years.

Heavy siltation occurred due to disturbance and deforestation in the catchment area. Poor participation of the farmers was also mentioned as the main threats. Only 28% of the village had WUA and farmer's co-operation for collective work was much less. Importance of agriculture and there by tanks was diminished over the period of time. As most of the farmers (80%) opined that it was low or no profit business (Powar, 2007).

13. Impact of tank modernization

Table 12 and 13 show that modernization of tank would increase water availability 10 to 20 days in a crop season in 60% of tanks, the crucial factor which decide the tank performance. 40% of the modernized tanks were not to do so because of poor participation of the farmers and poor maintenance of the developed infrastructure. Regarding number of crops grown per year and type of crops there is not much change. But now almost all the tank farmers started to cultivate short duration varieties like ADT 39, ADT 43, Co 43, and ASD 16. Farmers were not aware of the level of ground water use before and after modernization. But most of the farmers felt that quality of drinking water was improved. Rearing of livestock came down drastically due to non- availability of fodder. Investment in farms also decreased over the period of time because of drought in the last three years and, at the same time, increasing demand for labour. However, most of the younger generation were not willing to do agricultural activities and hence, migrated out for their livelihood.

Cooperation among the farmer was good, wherever water users association existed or local traditional leadership was strong. Disputes among the farmers were settled down amicably by WUAs. Even though all the villages have self-help group

Table 12. Impact of Tank Modernization

Indicators / Village	A		B		C		D		E		F		G		H		I		J	
	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM
1	90	100	2	2	P,C	P,C	-	Yes	Same	Same	Good	Good	Same	Same	5000	7000	Yes	Yes	Same	same
2	40	50	2	2	p	p	No	No	Same	Same	Good	Good	Low	Low	5000	8500	Yes	Yes	Low	low
3	90	90	2	2	p	p	No	No	Same	High	Good	Good	Same	Same	5000	5000	No	No	Low	low
4	40	50	1	1	p	p	No	No	Same	Same	Good	Good	Low	Low	5000	7000	No	Yes	High	low
5	40	50	1	1	p	p	No	No	Same	Same	Good	Good	Low	Low	5000	6500	No	No	Low	Low
6	40	50	1	1	p	p	No	No	Same	Same	Good	Good	Low	Low	4800	9000	No	Yes	High	Low
7	40	50	1	1	p	p	No	No	Same	Same	Good	Good	Low	Low	4500	8000	No	No	High	Low
8	30	30	1	1	p	p	No	No	Same	Same	Good	Good	Low	Low	4000	7000	Yes	Yes	High	Low
9	90	90	2	2	p	p	No	No	Same	Same	Good	Good	Low	High	5000	5000	No	Yes	Low	Low
10	100	120	1	1	p	p	No	No	Same	Same	Good	Good	Low	Low	5000	6000	No	No	High	low
11	30	30	2	2	p	p	No	No	Same	Same	Good	Good	Same	Same	5500	8500	Yes	Yes	Same	same
12	60	70	2	2	p	p	No	No	Same	Same	Good	Good	Low	Low	6000	8600	No	Yes	Low	Low
13	120	100	2	1	p	p	No	No	Same	Same	Good	Good	Low	Low	5000	5000	No	No	Low	Low
14	100	75	1	1	p	p	No	No	Same	Same	Good	Good	Same	Same	5000	5000	No	No	Same	same
15	60	70	1	1	p	p	No	No	Same	Same	Good	Good	Same	Same	5000	5000	Yes	Yes	Same	same
16	40	50	1	1	p	p	No	No	Same	Same	Good	Good	Low	Low	5000	7500	No	Yes	Same	same
17	40	50	1	1	p	p	No	No	Same	Same	Good	Good	Low	Low	4800	5500	No	Yes	Same	same
18	120	120	2	2	p	p	No	No	Same	Same	Poor	Good	Low	Low	5000	5000	No	No	Same	same
19	80	50	2	1	p	p	No	No	Same	Same	Good	Good	Low	Low	5000	7500	Yes	Yes	High	Low
20	30	40	1	1	p	p	No	No	Same	Same	Good	Good	Same	Same	5000	5000	Yes	Yes	High	Low
21	90	60	2	2	p	p	No	No	Same	Same	Good	Good	Low	Low	5000	5000	Yes	Yes	High	Low
22	40	40	1	1	p	p	No	No	Same	Same	Good	Good	Low	Low	6500	7000	No	Yes	High	Low
23	80	75	1	1	p	p	No	No	Same	Same	Poor	Good	Low	High	6000	7000	No	No	Low	Low
24	75	80	2	2	p	p	No	No	Same	Same	Poor	Poor	Low	Same	6000	6000	Yes	Yes	Low	low
25	120	90	1	1	P	P	No	NO	Same	Same	Good	Good	Low	Low	5500	7000	No	No	Low	Low

BM : Before Modernization AM : After Modernization

Indicators : A Water availability(days) B. crops grown per year C. type of crop D. change in crop pattern E. groundwater availability F.drinking water G. livestock population H. farm income/Rs/acre I. equity in distribution of water J. labour availability

Crops : P – paddy, C- Cumbu

Table 13 Impact of Tank Modernization (Contd…),

Village/ indicators	K		L		M		N		O		P		Q		R		S		T	
	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM	BM	AM
1	No	No	No	No	No	No	Same	Same	Yes	Yes	No	No	Same	same	Low	Same	Yes	Yes	-	-
2	No	No	No	No	No	No	Low	Low	No	No	No	No	-	Low	Low	High	-	-	-	-
3	No	No	No	No	No	No	Low	Low	No	No	No	No	Same	Same	Low	Same	No	No	-	-
4	No	No	No	No	No	No	Low	High	Yes	Yes	No	No	-	High	Low	High	Yes	Yes	-	-
5	No	No	No	No	No	No	-	High	No	No	No	No	-	High	Low	High	No	No	-	-
6	No	No	No	No	No	No	No	High	No	No	No	No	Same	Same	Low	High	Yes	Yes	-	-
7	No	No	No	No	No	No	No	High	Yes	Yes	No	No	Same	Same	Low	High	Yes	No	-	-
8	No	No	No	No	No	No	Low	High	No	No	No	No	Same	Same	Low	High	Yes	No	-	-
9	No	No	No	No	No	No	Low	High	Yes	Yes	No	No	Same	Same	Low	Low	No	No	-	-
10	Yes	Yes	No	No	No	No	No	High	No	No	No	Yes	Same	Same	Low	Low	No	No	-	-
11	No	No	No	No	No	No	Same	Same	Yes	Yes	No	No	Same	Same	Low	High	Yes	No	-	-
12	No	No	No	No	No	No	Same	Same	No	No	No	No	Same	Same	Low	High	Yes	No	-	-
13	No	No	No	No	No	No	Low	Low	No	No	Good	Good	Same	Same	Low	Low	No	No	-	-
14	Yes	Yes	No	No	No	No	Low	Low	No	No	No	No	Same	Same	Low	High	Yes	No	-	-
15	Yes	Yes	No	No	No	No	Low	Low	No	No	No	No	Same	Same	Low	High	Yes	Yes	-	-
16	No	No	No	No	No	No	Low	High	No	No	No	No	Same	Same	Low	Low	No	No	-	-
17	No	No	No	No	No	No	Low	High	No	No	No	No	Same	Same	Low	Low	No	No	-	-
18	No	No	No	No	No	No	Low	Low	Yes	No	No	No	Same	Same	Low	Low	Yes	Yes	-	-
19	No	No	Yes	Yes	No	No	Low	Low	Yes	Yes	No	No	Same	Same	Low	Low	Yes	Yes	-	-
20	No	No	Yes	Yes	No	No	Low	Low	Yes	Yes	No	No	Same	Same	Low	Low	Yes	Yes	-	-
21	No	No	Yes	Yes	No	No	Low	High	Yes	Yes	No	No	Same	Same	Low	Low	Yes	Yes	-	-
22	No	No	No	No	No	No	Low	Low	No	Yes	No	No	Same	Same	Low	Low	Yes	Yes	-	-
23	No	No	No	No	No	No	Low	Low	Yes	Yes	No	No	Same	Same	Low	Low	Yes	Yes	-	-
24	No	No	No	No	No	No	Low	Low	Yes	Yes	No	No	Same	Same	Low	Low	Yes	Yes	-	-
25	No	No	No	No	No	No	Low	Low	Yes	No	No	No	Same	Same	Low	Low	Yes	Yes	-	-

Indicators : K. Dispute among farmers, L. Water management, M. Fishing, N. Employment opportunity, O. Cooperation, P. SHG(Self Help Group) Q. No. of wells in the *ayacut*, R. Investment in farm structures S. social forestry, T. Others

BM :Before modernization, AM: After modernization

(SHG), their contribution to the tank management was meager as their main activities are relating to micro-finance. Some of the villagers felt that social forestry would provide some revenue to the villages; however, many farmers felt that it hindered the tank performance due to the siltation of the tank-beds and foreshore area. The mean value of the tank performance and other variables influencing the tank performance are given in Table 14. It is observed that the mean value of tank performance in EEC tanks was 82% compared to 78% in the Non-EEC Tanks, and the difference is not significant.

Table 14. Mean Value of Variables Influencing Tank Performance among Tanks

Parameters	EEC Tanks	Non-EEC Tanks
Tank performance (%)	82	78
Filling pattern (no. of times)	1.36	1.28
Water availability (no. of days)	56.5	52.2
Siltation (%)	36	47
Presence of WUA (%)	36	28
Farmer's participation (%)	40	42
Presence of *Neerkatti* (%)	68	64
Maintenance of tanks (%)	44	36
Farm income (Rs/acre)	6240	5975
Water management (%)	12	12
Equal water distribution (%)	40	38
Employment opportunity (mandays)	40.0	40.0
Cooperation among farmers (%)	44	40
Encroachment %)	36	45
Well density (no. of wells/ ha.)	9	11

Table 15. Correlation between Tank Performance and Socio-Economic and Hydrological Characteristics of EEC Tanks

S.No	Independent variables	Correlation value
1	Filling pattern	0.022
2	Water availability	0.183
3	Level of encroachment	-0.487*
4	Percentage of siltation	0.012
5	Presence of water user association	0.071
6	Presences of *Neerkatti*	0.183
7	Participation of farmers	0.327
8	Government support	0.064
9	Maintenance of tanks	0.109
10	Farm income	0.340
11	Equal water distribution	0.218
12	Dispute among farmers	0.066
13	Adoption of water management practices	0.413*
14	Employment opportunity	0.473*
15	Cooperation among farmers	-0.129
16	Well density	0.002
17	Caste composition of *ayacut*	-0.229

Correlation is significant at the 0.05 level (2 tailed)

Out of 16 variables studied, adoption of water management practices and employment opportunities were found to be significantly positive at 5% level of probability. On the other side, levels of encroachment were found significantly negative at 5% level of probability. The remaining variables have shown non-significant relationship with tank performance.

The average man-days available in the study area may be around 120 days. In the last two years (2005 and 2006) this area received more than normal rainfall that ultimately resulted with more opportunity in the farm and allied sector. When they had opportunity to earn money, they were willing to contribute a minimum of about Rs. 100 per acre for the tank management. Hence, the tank performance was good.

Another variable, adoption of water management practices, also contributed positively to the better tank performance. It may be due to the fact that the farmers' management practices for water conservation would increase water availability in the tanks. From the year 2000 to 2004 there was severe drought in this area, and most of the farmers experienced crop failure and giving up the cultivation. So, the farmers learned from the past and motivated themselves to adopt water management practices like alternative wetting and drying, *orumadai patchal* (alternative closing of sluice) and *murai pasanam* (rotational way of irrigating farmers field by *Neerkatti*).

Level of encroachment in the tank components like foreshore area, catchment area, and the supply channel has significantly negative effects on the tank performance. Upto 50 % of encroachment was observed in the study area. The study shows that encroachment in the tank system reduced the water supply up to 30% (Palaniami and Easter 2000).

Correlation co-efficient was calculated to study the relationship between tank performance and socio-economic and hydrological characteristics of Non-EEC tanks (Table 16). Participation of farmers in the tank management and government support were found to be significantly positive. The employment opportunity also found to be significant and exhibited positive relationship. But at the same time, well density

and dispute between farmers contributed significantly negative to the tank performance.

Table 16. Correlation between Tank Performance and Socio Economic and Hydrological Characteristics of Non-EEC Tank

S.No	Independent variables	Correlation value
1	Filling pattern	0.196
2	Water availability	0.134
3	Level of encroachment	-0.131
4	Percentage of siltation	0.134
5	Presence of water user association	0.045
6	Presences of *Neerkatti*	0.178
7	Participation of farmers	0.403*
8	Government support	0.450*
9	Maintenance of tanks	-0.175
10	Farm income	0.143
11	Equal water distribution	-0.156
12	Dispute among farmers	-0.479*
13	Adoption of water management practices	-0.267
14	Employment opportunity	0.729**
15	Cooperation among farmers	0.128
16	Well density	-0.401*
17	Caste composition of *ayacut*	-0.104

* Correlation is significant at the 0.05 level (2 tailed)
** Correlation is significant at the 0.01 level (2 tailed)

After vanishing of *kudimaramathu* system of tank management, the people expect that the government will do the repair and maintenance work. Recently

government-executed watershed programmes such as Drought Prone Area Programme (DPAP) and Village Level Self-Sufficient (VLSS). These supported the tank maintenance to some extent but their impact on the overall tank performance was not studied.

Dispute among farmers and well density were negatively associated with the tank performance. Sakurai and Palanisami (2001) reported that increases in the number of wells in the *ayacut* area will decrease the tank performance. When number of wells increases in the *ayacut* area, it discouraged the collective action among the people which leads to dispute between farmers and ultimately affected the tank performance.

Since the role of WUAs is varying across the tanks, it was considered to analyze the factors influencing the performance of the WUAs. Accordingly, factors such as farm income, caste composition in the tank villages and government support in the form of support programmes were considered important.

To quantify the factors influencing the tank performance, a multiple linear regression analysis was carried out using tank performance as the dependent variable and number of factors such as filling pattern, water availability in the tank, level of encroachment, percentage of siltation to the total capacity, presence of water user's association, presence of *Neerkatti*, participation of the farmers in collective action, maintenance of the tank, government support to the tank management, farm income and farm investment, equal water distribution, dispute among farmers, adoption of water management practices, employment opportunity, cooperation among the farmers, well density and caste composition of the villages as independent variables.

The results are given in Table 17. The R^2 value 0.852 revealed that 85.20% of tank performance was explained by the independent variables included in the analysis.

Table 17. Multiple Regression Analysis of Socio-Economic and Hydrological Characteristics of EEC Tanks and Their Performance

S.No	Independent variables	Partial regression coefficient	Standard error of regression co efficient	t value
1	Filling pattern	0.638	0.246	2.590**
2	Water availability	0.137	0.262	0.524
3	Level of encroachment	-0.005	0.252	-0.230
4	Percentage of siltation	0.438	0.457	0.958
5	Presence of water user association	0.274	0.497	0.550
6	Presence of *Neerkatti*	-0.001	0.374	-0.049
7	Participation of farmers	-1.003	0.543	-1.846*
8	Maintenance of tanks	-0.828	0.308	2.691**
9	Government support	-0.561	0.378	-1.483
10	Farm income	0.316	0.201	1.575
11	Equal water distribution	-0.199	0.314	-0.633
12	Dispute among farmers	-0.821	0.378	-2.172*
13	Adoption of water management practices	-0.834	0.350	-2.383*
14	Employment opportunity	-0.008	0.566	-0.016
15	Cooperation among farmers	-0.290	0.506	-0.574
16	Well density	-0.565	0.345	-1.637
17	Caste composition of *ayacut*	0.151	0.137	1.101

R^2 = 0.852
F = 2.374
* = Significant at 0.05 % level
** = Significant at the 0.01% level

Among the variables that affect the tank performance, the stepwise multiple regression analysis was fitted as given below:

$Y_1 = 6.196 + 0.638 **X_1 + 0.137\ X_2 - 0.005\ X_3 + 0.438\ X_4 + 0.274\ X_5 - 0.0018\ X_6 -- 1.003*\ X_7 + 0.828**\ X_8 - 0.561\ X_9 + 0.316\ X_{10} - 0.199\ X_{11} - 0.821*\ X_{12} - 0.834*\ X_{13} - 0.008\ X_{14} - 0.290\ X_{15} - 0.565\ X_{16} + 0.151\ X_{17}$

It could be observed from the above equation that filling pattern ($X_{1)}$ and maintenance of the tanks (X_8) would increase the tank performance by 2.590 and 2.261% respectively. Variables like participation (X_7), dispute among the farmers (X_{12}) and water management (X_{13}) contributed negatively but significantly to performance of the EEC tanks.

These EEC tanks received only one filling per year but 10 year before it was 1.36 filling. As one filling can supply water for 60 days, farmers felt that at least 1.5 filling is needed to have successful harvest. Again, at present 36.2% of tank storage capacity has been reduced due to silt deposits in the water spread area of the tank. Hence, more than one filling is needed to provide the required supply to fields.

Regarding maintenance of the tanks, most of the EEC tanks have modernized the sluices and lined field canals. Hence, operation and maintenance of the sluices and lined canal were relatively easy. Often, the farmers were also engaged in the supply channel cleaning. So, all of these contributed towards the better performance of the EEC tanks.

On the other hand, participation of farmers was found to be negative on tank performance. This is because that farmer's participation was observed to be relatively high during water shortage period. Hence, whenever water scarcity becomes severe, participation by the farmers become more. However, due to reduced

Table18. Multiple Regression Analysis of Socio-Economic and Hydrological Characteristics of Non-EEC Tanks and Their Performance (n= 25)

S.No	Independent variables	Partial regression coefficient	Standard error of regression co efficient	t value
1	Filling pattern	-0.496	0.579	-0.857
2	Level of encroachment	-0.466	0.655	-0.712
3	Percentage of siltation	-0.225	0.528	-0.426
4	Presence of water user association	-0.317	0.527	-0.549
5	Presences of *Neerkatti*	0.316	0.568	0.556
6	Participation of farmers	0.303	0.527	0.575
7	Maintenance of tank	-0.774	0.676	-1.145
8	Government support	-0.286	0.507	-0.563
9	Farm income	0.399	0.506	0.789
10	Equal water distribution	0.399	0.775	0.514
11	Dispute among farmers	-1.022	0.911	-1.121
12	Adoption of water management practices	-0.780	0.434	-1.796*
13	Employment opportunity	-0.681	1.241	0.549
14	Cooperation	0.298	0.490	0.608
15	Well density	0.144	1.385	0.104
16	Caste composition of *ayacut*	-0.0033	0.192	-0.174

R^2 = 0.707
F = 1.207
* = Significant at 0.05 % level
** = Significant at the 0.01% level

storage, tank irrigated area was comparatively less and showing poor performance. In last two years there was no water scarcity resulting in lower level of participation. Given the reduced participation, disputes among the farmers in water sharing between head and tail, upper and lower sluices were observed.

The results of the multiple regression are presented in the Table18. The R^2 value was 0.707. Even though only 7 out of 17 variables were with positive sign but failed to establish significant contribution. Two variables, namely dispute among farmers (X_{11}) and adoption of water management practices by the farmers (X_{13}), were found significantly negative.

Most of the Non-EEC tanks have larger command area and thereby larger canals and greater difference among upper and lower sluices resulting in greater differences in the water availability among the farmers and those furthest from the tank received least amount of water compared to farmers who located close to the sluices.

In addition to that, when the tank size increased, numbers of farmers had also increased. Hence, cooperation became difficult with relatively larger population. When the cooperation among farmers were poor, it is understandable that dispute may come often. The poor cooperation and dispute among farmers ultimately resulted in poor performance of the Non-EEC tanks.

While comparing the performance of the EEC and Non-EEC tanks, there was no substantial difference in the overall performance. However, maintenance of the

Table 19.Multiple Regression Analysis of Socio-Economic Condition of the Village and Effectiveness of Water User Association in EEC Tanks

S.No	Independent variables	Partial regression coefficient	Standard error of regression co efficient	t value
1	Farm income	-0.0045	0.201	-0.229
2	Caste composition of *ayacut*	0.00145	0.081	0.181
3	Government support	0.2410	0.138	1.742*

Dependent variable: Effectiveness of WUA

$R^2 = 0.144$
F = 1.174
* Significant at the 0.05 % level

tank becomes easy after modernization and dispute among the farmers were also much less in the EEC tanks than in non-modernized tanks.

Multiple regression analysis was performed to find out the extent of contribution of each item towards performance of water user's association. The results are given in the Table 19.

The R^2 value, 0.144, confirmed that 14.4% of the variation in the effectiveness of water user association was exhibited by these three variables

Since F value (1.174) was significant at one per cent level of probability the prediction equation was fitted for effectiveness of water user's association with favorable socio-economic conditions as given below

$$Y_1 = 0.743 - 0.0045X_1 - 0.0014X_2 + 0.241^* X_3$$

It could be concluded from the above equation that the government support contributed positively and significantly. The implication of this is that an unit

increase in the variable, namely government support (X_3), would result in consequently lifting about 1.742 units in the effectiveness of water user's association. The reasons emphasized in the correlation analysis may also fitted here too.

The results of the multiple regression analysis showed that the contribution of the selected socio economic characteristics in explaining the variation of the effectiveness of the water user's association was only 12.20% ($R^2 = 0.122$).

Table 20. Multiple Regression Analysis of Socio-Economic Condition of the Village and Effectiveness of Water User Association in Non-EEC Tanks

S.No	Independent variables	Partial regression coefficient	Standard error of regression co efficient	t value
1	Farm income	0.286	0.221	1.295
2	Caste composition of *ayacut*	-0.006	0.074	-0.890
3	Government support	0.0069	0.133	1.812*

$R^2 = 0.122$
F = 1.197
* Significant at the 0.05% level

Since, the F value (1.197) was significant at 0.05% level of probability; the prediction equation was fitted for effectiveness of water user's association as follow

$$Y_1 = 1.077 + 0.286\ X_1 - 0.0065\ X_2 + 0.069^*\ X_3$$

It could be observed from the above equation that the regression coefficient of government support (X_3) was positively and significantly contributed towards the better performance of water use's association. The government support in the form of World Bank modernization programme in the last few years might have helped the WUAs to survive.

The government support contributed positively and significantly in both EEC and Non-EEC tanks. The correlation analysis also showed significant relationship between government support and functioning of water user's association. It is apparent that when the government came forward to contribute money substantially through development programmes, it created confidence among the villagers to form and operate water user's association. There was no difference between EEC tanks and Non-EEC tanks in terms of effectiveness of water user's association

In the cases of farm income and caste composition, their influence is not significant. This may be due to the fact that all the study villages had multi-caste system and only 30 % of the villages have water user's association. Again, farm income also not contributed significantly towards the effectiveness of water user's association. Even if farm income increases over the period of time due to good rainfall as experienced for the past two years (2005 and 2006), the farmers were not willing to pay for tank improvement/maintenance. They were expecting that government will do everything for the tank management including formation of WUAs.

Variables like filling pattern of the tanks, water availability in the tank, presence of water user's association, presence of *Neerkatti* (waterman), co-operation among the farmers, dispute among the farmers while sharing the tank water and condition of tank physical structures might have influenced the performance between EEC and Non-EEC tanks. In order to test this, 't' test has been carried out (Table 21).

It could be interpreted from the table that two out of eight variables selected for the test, showed significant relationship. Condition of the tank structures and dispute among the farmers while sharing the water were considered as crucial

Table 21. Comparative t Test between Parameters Influencing Tank Performance in EEC and Non-EEC Tanks

	Variables	t value
1	Filling pattern	1.290
2	Water availability	1.010
3	Tank structures	2.102*
4	Water user's association	-0.596
5	Waterman	0.293
6	Cooperation among farmers	-0.278
7	Employment opportunity	0.770
8	Dispute among the farmers while sharing the water	2.028*

- significant at 10% level

variables which differentiated the performance between the EEC and Non-EEC tanks.

EEC programmes modernized the tank structures like sluices, surplus weir and canal below the outlet. Hence, it was easy to operate and maintain these structures by the waterman in the EEC tanks than in Non-EEC tanks. Outlet canals were also lined by EEC programme, hence, tank water released for irrigation reached tail ends relatively quickly than in Non-EEC tanks. However, canal lining was not done for entire command area of the tank. Maximum 50 % of the area was lined and average area under lined canal was much less.

Hence, it was concluded that even though EEC work has improved the tank performance than non modernized tanks but it was not up to the expectation of the farmers as there was no significant difference between EEC and Non-EEC tanks in terms of other parameters such as filling pattern, water availability etc.

Equity in Water Availability and Paddy Yield

Equity ratio is defined as yield in kg per acre in head reach / yield in kg per acre in tail reach. If the ratio is greater than one, it indicates that head reach is benefited much from irrigation. The ratio is close to one in modernized tanks compared to non-modernized tanks indicating that the modernization has improved the water supply and crop yield uniformly. Higher the ratio, wider the inequity in irrigation water distribution between the head and tail regions. The equity ratios for rice yield and water availability in EEC and Non-EEC tanks are presented in Table 22.

Table 22. Equity Ratio of Paddy Yield and Water Availability in EEC and Non-EEC Tanks.

Particulars	**EEC Tanks**	**Non-EEC Tanks**
Yield (kg/acre)		
Head reach	2520	2448
Tail reach	2376	2160
Equity ratio	1.06	1.13
Water Availability (No. of Irrigation/ acre)		
Head	27	25
Tail	27	23
Equity ratio	1.00	1.08

It is inferred that in EEC tanks, the equity ratio for the rice yield is 1.06 which indicates that when the yield of paddy was one ton/acre in tail, it was 1.06 ton/acre in head reach. In Non-EEC tanks the ratio was 1.13 which indicates there was a subtle difference between head and tail reach. Hence, it is concluded that distribution of available water between head and tail reach is comparatively better in

EEC tanks. This was due to the lining of the canal below the outlet which minimizes seepage losses considerably in EEC tanks. For Non-EEC tanks lining was not available hence the difference. Availability of water also marginally higher in EEC tanks than Non-EEC tanks. It might be due to modernized sluices and shutters provided in modernization programme. However, the difference between EEC and Non-EEC tanks is not significant in terms of equity ratio.

Conclusion

Tank modernization in a much broader sense could indicate the efficiency of the investment options. Most of the current activities involved rehabilitation below the outlet while tank modernization as such refers rehabilitation and improved water management.

In most of the EEC tanks the sluice was replaced with modernized one, tank bunds were strengthened, and outlet channels were lined assuming that all these will contribute positively to improve the tank performance. Even though, in EEC tanks, the water availability has increased from 10 to 20 days per season, the difference was not significant between EEC and Non-EEC tanks. Further, most of the other parameters such as tank filling pattern, crop yield and farm income, presence of WUA though looking favorable to EEC tanks, could not confirm that EEC modernized tanks had performed better than Non-EEC tanks. Possible reason for this seemingly acceptable outcome, might be due to poor follow up both by government and local institutions in maintaining the modernized components as the modernized works done were deteriorated over years and the tanks behaved like Non-EEC tanks. Also fund allotment for regular maintenance of the tanks was also negligible. Since water supply was uncertain due to erratic rainfall, farmers also lost interest in the up-keep of the tanks over years.

Hence, management of the modernized structures in the tanks is highly important in improving the overall tank performance. Separate budget provision in the modernization programmes should be provided towards periodical repair and maintenance works. Water user's organizations should be revived through special programmes so that tank modernization could be made more effective. In the event of budget constraints for future tank modernization programmes, only those components that will have comparatively more impact such as lining the canals than other components such as repairs on sluices and surplus weirs should be given priority.

In the future modernization programs, those tanks that may offer more scope for post project maintenance should be given priority. These include tanks with strong WUAs, less conflict due to caste cum politics, moderate number of wells and opportunities for enhancing multiple uses. Also selective modernization options relating to individual tanks should be given priority.

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References

Government of Tamil Nadu (1986). PWD Official Record about Tank Modernization Work.

Palanisami.K (2001). *Tank Irrigation*, Asian Publication Services, New Delhi

Palanisami.K and Easter K.W (2000). *Tank Irrigation in the 21st Century-What Next?* Discovery Publishing House, New Delhi

Powar Sarath (2007). Agriculture and Rural Development, Parliament Talk, Minister for Agriculture, Govt. of India, *The Hindu* dated July 28.

Sakurai and Palanisami.K. (2001). Tank Irrigation Management as a Local Common Property: The Case of Tamil Nadu, India. *Agricultural Economics*, 25, 273-283.

Appendix 1. The EEC Tank Location in the Chain

S. No	Tank chain	Madurai District	Ramanathapuram District	Sivagangai District	Virthunagar District
1	Tank chain Tanks	Keelakuyil kudi Chain 1.Vadapalnchi 2.Melakuyilkudi 3.Keelakuyilkudi 4.Vadivelkarai	Maravakudi chain 1.Puseri 2.Maravakudi 3.Sikkal Nadukkal 4.Sokkarai 5.Vallakulam 6.Sikkal	Kovanur chain 1.Pillur 2.Arasani 3.Kovanur 4.Kalathur	Pullalakottai Isolated
2	Tank chain Tanks	Nallur - Isolated tank	Vallakulam chain 1.Puseri 2.Maravakudi 3.Sikkal nadukkal 4.Sokkarai 5.Vallakulam 6.Sikkal	Nallakulam chain ***1.Nallakulam*** 2.Karumpavur	Vadmalkurichi Isolated
3	Tank chain Tanks	Othai alankualm ***1. Sambakulam*** 2.Kuthiyarkundu 3. Othai alankulam 4. Ulagani	Punnavasal chain 1.Maranthai 2.Velankurichi 3.Punnavasal	Nattakudi chain 1.Nattakudi 2.Elanthakudi	Vellur chain 1.Kadaneri ***2.Vellur***
4	Tank chain Tanks	Sambakualm chain 1.Nilaiyur 2.Sambakualm 3.Othai algankualm 4. Ulagani	Athanakothkudi Isolated tank	Periyakannanur chain 1.Nemmeni 2.Periyakannanur 3.Kadambakudi	Pudukottai chain 1.Pudukottai 2.Nallayankualm 3.Kothaneri
5	Tank chain Tanks	Ayyan pappakudi - Isolated tank	***Chitrankudi*** Isolated tank	Pilur chain 1.Pillur 2.Arasani 3.Kovanur 4.Kalathur	Mannarkottai Chain 1.Mannarkottai 2.Kalaperumalpatti
6	Tank chain Tanks	Melakuyil kudi chain 1.Vadapalanchi 2.Melakuyilkudi 3.Keelakuilkudi 4.Vadivelkarai	Enathi chain 1.Enathi 2.Poongulam	Sakkur chain 1.Sakkur 2.Anjavayal	Nenmeni chain 1.Kollapatti 2.Nenmeni 3.Mudithalai

7	Tank chain Tanks	Kudicheri chain 1.Saptur ***2.Kudichery*** 3.Athipatti 4.Mangelrev 5.Poolampatti	Sikkal chain 1.Puseri 2.Maravakudi 3.Sikkal nadukkal 4.Sokkarai 5.Vallakulam 6.Sikkal	Usilankulam 1.Paluvakodai 2.Usilankulam 3.Kandakalai	Ayyampatti chain 1.Subramaniyapuram 2.Ayyampatti
8	Tank chain Tanks	Periyapoolankualm Isolated tank	Kidathirukal chain 1.Kidathirukal 2.Koorakootam 3.Pothikulam 4.Oruvandal	Valuthani chain 1.Valuthani 2.Periyakottai	Melamadai chain 1.Melamadai 2.Onampatti
9	Tank chain Tanks	Allapalacheri chain 1.Allapalacheri 2.Appakarai 3.Naduvakottai	Pothikualm chain 1.Kidathirukal 2.Koorakootam 3.Pothikulam 4.Oruvandal	Padamathur chain 1.Thukkalur ***2.Padamathur***	Kilamarainadu Isolated
10	Tank chain Tanks	Arasapati chain 1.Sivarakottai 2.Arasapatti 3.Pottalpacheri 4.Valayankulam 5.Thoombakulam	Keelasirpodhu chain 1. Melasirupodhu 2. Keelasirupodhu 3.Kolikulam	Mudikarai chain Isolated	Vembakottai Isolated
11	Tank chain Tanks	Chittur chain 1.Sevelkulam 2. Thennamanallur 3. Chittur 4.M.Puliyankulam	Melasirupodhu chain 1. Melasirupodhu 2. Keelasirupodhu 3.Kolikulam	Mudikondan chain 1.Mudikondan big tank 2.Mudikondan 3.Ilanthakulam	Muthunaikanpatti chain 1.Vethilaiyurani 2.Subramaniyapuram 3.Muthunaikanpatti
12	Tank chain Tanks	Kunnathur chain ***1.Kunnathur*** 2.Villur 3.Overy 4.Chitur 5.Puliyankulam 6.Tennamanallur 7.Adanur 8.Iyyanarkualm 9.Venkadasamudram 10.Vettarayankulam 11.Maitanpatti 12.Illupaikualm	Kottayendal chain 1.Poolankulam 2.Kottaiyendal 3.Selvanur	Thevathakudi chain 1.Karaikulam 2.Thevathakudi	Nalli big tank Isolated

15	Tank chain Tanks	Maitanpatti chain 1.Kunnathur 2.Villur 3.Overy 4.Chitur 5.Puliyankulam 6.Tennamanallur 7.Adanur 8.Iyyanarkualm 9.Venkadasamudram 10.Vettarayankualm 11.Maitanpatti 12.Illupaikualm	Koorankulam chain 1.Kidathiraki 2.Koorankulam 3.Pothikulam	Nagamugathankudi 1.Vijayankudi 2 .Nagamugathan 3.Thiruvallur	Kadambakulam chain 1.Kadambakualm 2.Karunkulam 3.Kelarajakularam
16	Tank chain Tanks	Maikudi Isolated tank	Orivayal chain 1.Panaikulam 2.Orivayal 3.Selvanur	Sathamangalam chain 1.Devathakudi ***2.Sathamangalam*** 3.Kalaikulam 4.Kovaikulam	Cholapuram chain 1.Kulasekaraperi 2.Cholapuram
17	Tank chain Tanks	Melanesaneri Isolated tank	***Theriruveli*** Isolated tank	Thaliyamangalam Chain 1.Pottavayal 2.Thottikurichi 3.Thaliyamangalam 4.Thayamangalam	Vadakaraikulam 1.Kurichiyarpathi 2.Vadakarai 3.Puliyankulam
18	Tank chain tanks	Overy chain 1.Kunnathur 2.Villur 3.Overy 4.Chitur 5.Puliyankulam 6.Tennamanallur 7.Adanur 8.Iyyanarkualm 9.Venkadasamudram 10.Vettarayankualm 11.Maitanpatti 12.Illupaikualm	Thirruveli small tank Isolated tank	Thiruvallur chain 1. Vijayankudi 2 .Nagamugathan 3.Thiruvallur 4. Kannamangalam	Sundarrajapuram 1.Koravankulam ***2.Sundarrajapuram*** 3.Sethanerikulam
19	Tank chain Tanks	Sivarkottai chain 1.Sivarakottai 2.Arasapatti 3.Pottalpacheri 4.Valayankulam 5.Thoombakulam	Ekkakudi chain 1.Ekkakudi 2.Pakripudukulam 3.Nallankudi	Visvanur chain 1.Udayanur 2.Visvanur	Solaiseri chain 1.Poovaneri 2.Solaiseri 3.Pirakudi 4.Kollankondam

20	Tank chain Tanks	Sowdarpatti chain 1.Thankalacheri ***2.Sowdarpatti*** 3.Kilavaneri 4.Ponnampatti	Mallal chain 1.Sekkara valnthur 2.Sambai 3.Mallal	Arasankulam chain 1.M.Pudukulam 2.Arasankulam	Naduvakulam 1.Naduvakualm 2.Kadappakudi 3.Kollankondam
21	Tank chain Tanks	Thangalacheri chain 1.Thankalacheri 2.Sowdarpatti 3.Kilavaneri 4.Ponnampatti	Atiyur chain 1.Kuruthankudi 2.Adathakudi 3.Athiyur 4.Anjukottai 5.Muhilthagam	Arimandapam chain 1.Arimandapam 2.Anavasal 3.Melapasalai	Mettupatti chain 1.Mettupatti 2.Kulasekaraperi 3.Gnapathikulam
22	Tank chain Tanks	Thennamanallur chain 1.Kunnathur 2.Villur 3.Overy 4.Chitur 5.Puliyankulam 6.Tennamanallur 7.Adanur 8.Iyyanarkualm 9.Venkadasamudram 10.Vettarayankualm 11.Maitanpatti 12.Illupaikualm	Akkalur chain 1.Adathakudi 2.Nagarikathan 3.Akkalur	Maruthanganallur chain 1.Karaikudi 2.Maruthaganalur 3.Keelpidanur	Valavanthan chain 1.Valavanthan 2.Naduvakualam 3.Kadpakudi
23	Tank chain Tanks	Thevankurichi chain 1.Thevankurichi 2.T.Kallupattti 3.Nallamaram 4. Vaiyur 5. Ammapatti	Anjukottai chain 1.Kuruthankudi 2.Adathakudi 3.Athaiyur 4.Anjukottai 5.Muhilthagam	Velur chain 1.Sirukudi 2.Velur	Srivilliputhur chain ***1.Srivillputhur*** 2.Athikulam 3.Nakkamangalam
24	Tank chain Tanks	Thirali Isolated tank	Chinnatondi chain 1.Nagarikathan 2.Seemavayal 3.Chinnathondi	Sambaikulam chain 1.Sambaikulam 2.Markualm 3.Visvampatti 4.Idaikattur 5.Seithanalur	Padikasuvaithanpatti 1.Edayankualam 2.PK Patti
25	Tank chain Tanks	Thoombakualm chain 1.Sivarakottai 2.Arasapatti 3.Pottalpacheri 4.Valayankulam 5.Thoombakulam	Kulathur chain 1.Nambuthaladi 2.Saliyakudi 3.Kadambanendal 4.Kulathur	Viswampatti chain ***1.Sambaikulam*** 2.Markualm 3.Visvampatti 4.Idaikattur 5.Seithanalur	Kilarajakularaman 1.Karunkulam 2.KR.Raman 3.Pappankulam

26	Tank chain Tanks	Ulagani chain 1.Nilaiyur 2.Sambakualm 3.Othai algankualm 4. Ulagani	Nambuthalakudi chain 1.Manjur 2.Mallikudi 3.Mankalakudi	Eluvankottai chain 1.Eluvan kottai 2.Thennivayal	Maharajapuram 1.Maharajapuram 2.Alagankua;m 3.Medankualm
27	Tank chain Tanks	Vadakarai chain 1.Vadakarai 2.Koorankulam	Orasur chain 1.Thoothakudi 2.Arunthoor 3.Orasur	Kappalur chain 1.Kapalur 2.Sadiyamangalam 3.Kandiyur 4.Kannankudi	Kottaiyur chain **1.Kottaiyur** 2.Tirumagalkulam 3.Nathampatti
28	Tank chain Tanks	Vidathakulam chain 1.Thavalaikulam 2.Vidathakulam 3.Ettunali kanmoi	Oriyur chain 1.Udayansamudrum ***2.Oriyur***	Tirippukottai chain 1.Tiruppukottai 2.Aeranikottai	Thambipatti chain 1.Vannankulam ***2.Thtiambipatti*** 3.Chttikurichi 4.Alganeri 5.Tirumagal
29	Tank chain Tanks	Villur chain 1.Kunnathur 2.Villur 3.Overy 4.Chitur 5.Puliyankulam 6.Tennamanallur 7.Adanur 8.Iyyanarkualm 9.Venkadasamudram 10.Vettarayankualm 11.Maitanpatti 12.Illupaikualm	Thakirmarukur chain 1. Nagrimuthu ***2.Thalirmarukur*** 3.Palankulam 4.Athiyankudi 5.Illuppakudi	Unjanai Isolated	Cholankualm Isolated
30	Tank chain Tanks	Elumalai Isolated tank	Thiruvettiyur chain 1.Muhilthagam 2.Thiruvettiyur 3.Orasur	Algansirukudi chain ***1.Algansirugudi*** 2.Vadamavalli	Paralachi chain 1.Kanjampatti 2.Paralachi 3.Vagaikualm 4.Kannakikulam
31	Tank chain Tanks	Saptur chain ***1.Saptur*** 2.Kudichery 3.Athipatti 4.Mangelrev 5.Poolampatti	Idayathur chain 1.Idayathur 2.Veppankualm 3.Karujakulam 4.Sembiankudi 5.Kelaparithiyur	Athani Isolated	Chatrapuliyakulam Isolated

32	Tank chain Tanks	Thirumanikam chain 1.Sulapuram 2.Chokkanathan 3.Thirumanikam 4.Athikaripatti 5.Mochikulam 6.Sembarani	Kallikudi chain 1. Puthur .p 2. Kallikudi 3.Rajakambiram	Alavanthan chain 1.Puduvayal 2.Alavanthan 3.Maniyarampatti 4.Mavilipatti	Nangor chain 1.Karuvakudi 2.Nangoor 3.Peekkulam 4.Nedunkulam
33	Tank chain Tanks	Adanur chain 1.Kunnathur ***2.Adanur*** 3.Muthappanpatti 4.Tennamanallur	Keelaparithiyur chain 1.Idayathur 2.Veppankualm 3.Karujakulam 4.Sembiankudi 5.Kelaparithiyur	Kothamangalam chain 1.Thammani 2.Kothamangalam 3.Kanadu Kathan	Mustakurichi Isolated
34	Tank chain Tanks		Melamathur chain Isolated tank	Parayanvayal Isolated	Papanam chain 1.Kambikudi 2.Papanam 3.Puliyakualm
35	Tank chain Tanks		P.Pudur chain 1. Puthur .P 2. Kallikudi 3.Rajakambiram	Piranbuvayal chain 1.Piranbuvayal 2.Pallathur 3.Nemmai	Kilavaneri chain Isolated
36	Tank chain Tanks		***Mosukudi*** Isolated tank	Semmanur chain 1.Semanur 2.Marutham	Mudukkankulam 1.Mudukankulam 2.Karunkulam 3.Nedunkulam
37	Tank chain Tanks		Siruvayal chain 1.P.Kodikulam 2.Vanniyur 3.Siruvayal	Thammani chain 1.Thammani 2.Kothamangalam	Puliyaran Isolated
38	Tank chain Tanks		Tharai kudi chain 1.T. Kallikulam **2.A.Tharaikudi** 3.Nagarathakurichi	Aralikottai chain ***1.Aralikottai*** 2.Madakupatti. 3.Ammapatti 4.Gowripatti	Pudupatti chain Isolated
39	Tank chain Tanks		Kadamangalam chain 1.Ponthampuli 2.Kadamangalam 3.Avathandai	Avanthi chain 1.Kongarathi 2.Avanthi 3.Mavinjipatti	Maraiyur Isolated

40	Tank chain Tanks		Ponthampuli chain 1.Ponthampuli 2.Kadamangalam 3.Avathandai 4.M.Pudukulam	Sithamalli chain 1.Sithamalli 2.Kalapur	Melaparuthiyur chain 1.Varisaiyur 2.Melaparuthiyur 3.Viracholan
41	Tank chain Tanks		M.Pudukulam chain 1.Ponthampuli 2.Kadamangalam 3.Avathandai 4.M.Pudukulam	Kallmapatti Isolated tank	Senilaikudi Isolated
42	Tank chain Tanks		Kovilankulam chain 1.Kundulkulam 2.Mustakurichi 3.Usampottal 4.Kovilamgualm	Eluvani chain 1.Algansirukudi 2.Vadmavalli 3.Eluvani	Velankudi chain 1.Mayaleri ***2.Velankudi*** 3.Surakualm
43	Tank chain Tanks			Mathavarayanpatti chain 1.Bothani 2.Muraiyur 3.Mathavarayanpatti 4.Karuppur	Thiruchuli Isolated
44	Tank chain Tanks			Kottaiyirruppu Isolated	Mugavoor chain 1.Valavanthan 2.Mugavoor 3.Thondamangulam 4.Sengulam 5.Maruthuvaneri
45	Tank chain Tanks			Manali chain 1.Sevvur 2.Ayinipatti 3.Ubaya Tank 4.Manali 5.Veliyan Kudi 6.Sundakadu	
46	Tank chain Tanks			Muraiyur chain 1.Bothani 2.Muraiyur 3.Mathavarayanpatti 4.Karuppur	
47	Tank chain Tanks			Nerkuppai chain **1.Nerkuppai** 2.Mithilai 3.Velankudi 4.Terkur	
48	Tank chain			Perumaruthur chain 1.Perumarithur	

	Tanks			2.Vinayagam Tank 3.Enathi	
49	Tank chain Tanks			Vanjinipatti tank 1.Kilamadam 2.Vanjinipatti 3.Periyakavini	

Note: Tanks with bold and italic were selected tanks

Appendix 2. PWD Officials Address in the Study Area

S.No	Places	Contact Persons
1	Gundar Basin Madurai Division	Mr Sivasankaran B.E., Executive Engineer. Mr Sukumar , A.E 9842177344 Mr Kajamoideen, A.E (Tech)
2	Tirumangalam Sub Division	Mr K Paramsivam, J.E 9344109846 Ms Vimala, Technical assistant
3	Usilampatti Sub Division	Mr K Tharumaraj, AEE Mr R.Pandi, AE 9443415578
4	Kariyapatti Sub Division	Mr Palanisamy, AE 9344103716 Mr Ramanathan JE 9865669695 Mr Muruganantham, JE 9486288037
5	Vaipar Division Viruthunagar	Mr SP Pandiyan, EE Mr Oorkavalan AEE 9443396624 Mr Palanivel, JDO Mr Manickam,JDO Mr Muthusamy,JDO
6	Aruppukottai SubDivision	Ms Niraimathi AE
7	Sattur SubDivision	Mr Prabhakaran, AE
8	Upper Vaipar Division Rajapalayam	Mr Rustham Ali, EE 04563 – 231354 Mr Alagarsamy,AE 9443487249
9	Srivilliputhur Sub Division	Mr Gnasekhar,AEE 94437 31635
10	Sarugani Division Sivagangai	Mr Chokkalingam, AEE
11	Devakottai SubDivision	Mr Karthikeyan,AEE
12	Paramakudi SubDivision	Mr Padmanathan,AEE 04564 - 231354
13	Mukukulathur Sub Division	Mr Shanmugam, AE

Appendix 3. List of Selected Tanks for the Study

EEC TANK VILLAGES		NON-EEC TANK VILLAGES	
Madurai District		**Madurai District**	
S.No	**Village Name**	**S.No**	**Village Name**
1	Sambakulam	1	Kilankulam
2	Kudisery	2	Koovalapuram
3	Kunnathur karisalkulam	3	Nilaiyur big tank
4	Adanur	4	Silaimalai patti
5	Sowdarpatti	5	Ponnampatti
6	Saptur	6	Jari usilampatti
Viruthunagar District		**Viruthunagar District**	
7	Kottaiyur	7	Kambikudi
8	Srivilliputhur	8	Mayaleri
9	Sundrarajapuram	9	Salvarpatti
10	Thambipatti	10	A.Puthupatti
11	Vellur	11	Watrap
12	Velangudi	12	Ayartharmam
Ramanathapuram District		**Ramanathapuram District**	
13	Mosukudi	13	Sekkanthidal
14	Oriyur	14	Kalangapuli
15	Thalirmarukur	15	Sikkal
16	A.Tharaikudi	16	Maranthai
17	Theriruveli	17	Vikaramapandiyapuram
18	Chittrangudi	18	T.Kallikulam
Sivagangai District		**Sivagangai District**	
19	Nallakualm	19	Arasani Muthupatti
20	Padamathur	20	Sakkanthi
21	Sathamangalam	21	Eriyur
22	Alagansirukudi	22	Piramanur
23	Aralikottai	23	Poovanthi
24	Nerkuppai	24	Theli
25	Sambaikulam	25	Thoothai