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THE MANAGEMENT, PRODUCTION, AND REHABILITATION
IN SOUTH INDIAN IRRIGATION TANKS

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WATER MANAGEMENT AND POLICY WORKSHOP PAPER

THE MANAGEMENT, PRODUCTION, AND REHABILITATION IN SOUTH INDIAN IRRIGATION TANKS

by

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THE MANAGEMENT, PRODUCTION, AND REHABILITATION IN SOUTH INDIAN IRRIGATION TANKS

K. Palanisami and K. William Easter*

Many of the South Indian tanks are starting their second hundred years in a sad state of disrepair.[1/] Although tanks are found in all parts of India, they account for over 30 percent of the total irrigated area in Andhra Pradesh, Karnataka and Tamil Nadu States of South India. There are about 39,200 tanks in Tamil Nadu State alone. However, until recently, tank irrigation has not been considered as an important source of irrigation. The major emphasis since 1950-51 has been on groundwater development and large scale irrigation projects. This coupled with poor tank management pushed tank irrigation into the background. However, financial and physical constraints to further development of groundwater and large projects have now brought tank irrigation back into consideration as a viable alternative for future expansion of irrigation, particularly in South India. Still, little effort has been made to study the feasibilities of using tanks as a viable alternative for expanding the irrigated area and production.

To help fill this research gap, the University of Minnesota and Tamil Nadu Agricultural University started a study of tanks in Tamil Nadu

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1/ An irrigation tank is a small reservoir constructed across the slope of a valley to catch and store runoff water. Generally, the tanks have a maximum depth of not more than 15 feet, although the depth varies up to 25 to 30 feet. Medium sized tanks have the capacity of about 100 million cubic feet.

in 1981. Ramanathapuram District was selected as the study area because over one-quarter of the Tamil Nadu tanks are in the District. In addition, 75 percent of the State's ten thousand Ex-zamin tanks are located in the District.[2/]

The major focus of the study was to identify the major constraints to improving tank performance. The study was divided into two parts. The first part was a detailed analysis of the water management and crop production in ten tanks during 1981-82 (see Table 1). The second part was a survey of 41 additional tanks in 1982-83 to determine what factors should govern the selection of tanks for rehabilitation. This paper provides a brief discussion of both phases of the study.

Tank Management

During a normal year like 1981-82, rice is grown during the tank irrigation season (October-March). The number of farms per tank varied from 49 in Tank 10 to 1,086 in Tank 4. The average farm size is 1.80 acres. The primary sources of water to dependent tanks are reservoirs and rivers while for independent tanks, the major source is runoff from rainfall.[3/] During periods of monsoon failure, the independent tanks have inadequate water. In at least half of the past ten years, seven of the independent tanks did not receive even enough water to adequately irrigate one crop and

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[2/] Ex-zamin tanks are the non-standardized tanks and are likely to be the ones faced with the greatest management problems.

[3/] In this study a modified classification of the tanks -- dependent and independent tanks -- was adopted. The dependent tanks are ones which received adequate supplies in most of the years for at least one crop and have a perennial source of supply such as a river. Independent tanks are those which did not receive adequate supplies in most years.

TABLE 1. Sample of Ten Tanks

Number	Name of Tank	Command Area	Tank Type[a/]
		(acres)	
1	Srivilliputhur Tank	993	Non-system
2	Watrap Big Tank	913	System
3	Piramanur Tank	1,590	System
4	Rangian Tank	1,166	Non-system
5	Ramalingapuram Tank	187	Non-system
6	Palavanatham Tank	234	Non-system
7	Nathampatty Tank	393	System
8	Medankulam Tank	134	System
9	Teli	86	Non-system
10	Thuthai	93	System

[a/] A modified classification to represent the tank type was made based on the water adequacy in the tanks. Accordingly, Tanks 2 and 3 were classified as dependent tanks and others as independent tanks. This replaces the old classification where system tanks are those which receive supplemental water from major streams or reservoirs in addition to the runoff from their own catchment.

used private well water after the tank water was gone. During the same ten years, farmers served by the dependent tanks had only two years when water was not adequate to irrigate two crops. In those two years the water supply was adequate to irrigate one crop.

Water scarcity and the higher price of private well water provided strong incentives for adoption of water distribution and management strategies both at tank and farm level (see Table 2). The two dependent tanks, 2 and 3, with their perennial water source, did not adopt a management strategy in 1981-82. In addition, the main canals of Tank 3 had been lined by the Irrigation Department to reduce water losses. Tank 9 received adequate water through unauthorized diversions of water destined for other tanks. This has led to a court case against the villagers. Yet, a community well has recently been installed in Tank 9 due to farmers' efforts to supplement tank water.

Farmers from Tanks 7 and 8 tried to obtain water from the Pilavakal Dam. The Pilavakal Dam was constructed during 1975-76 to collect the runoff from the mountain catchments which originally fed a number of tanks including Tanks 7 and 8. During the planning and construction periods, irrigation officials thought that water would be provided to 37 tanks including Tanks 7 and 8. But no canal was provided to allocate the water from the Pilavakal Dam to each tank in the series. Thus, water had to flow through one tank before it could irrigate another tank. The end result is an overuse of water in the upper tanks such as Tank 2 and inadequate water for the lower tanks. Farmers complained that the runoff which they received prior to the dam construction was larger than the water releases from the dam. Consequently, farmers from Tanks 7 and 8 demanded more water and received some additional water from the dam.

TABLE 2. Farmer Strategies to Meet Inadequate Tank Water Supplies, 1982.

Strategies	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8	Tank 9	Tank 10
Rights to perennial sources		X	X							X
Water Diversions	X[a]								X[c]	
Group Pressure on irrigation officials							X	X		
Community Wells				X					X[b]	
Canal Lining			X							
The cooperation of well owners and farmers' organizations	X			X						
No attempt					X	X				

a/ Farmers also diverted the run-off from very long distances by employing laborers, when the tank is not adequately filled. Normally, many laborers will be hired to intimidate farmers from other tanks who are also trying to divert run-off to their tanks.

b/ Under construction.

c/ This is an illegal diversion.

In the case of Tank 4, additional supplies were made available through the installation of two community wells operated by the Panchayat unions. In other tanks, mainly due to the influence of the private well owners or adequate tank water supplies, community wells have not been installed.

For Tank 1, the primary source of additional water is private wells. In years when the tank is only half filled by rainfall and run-off, farmers ask the well owners to cooperate in sharing their well water (for a price), after the tank supply is exhausted. The other strategy, combined with the above, is to maintain strict rotation schedules so that farmers receive tank water every four to six days rather than on a continuous basis. During periods of limited tank water supplies, water deliveries are reduced to half of normal releases. This is achieved through the efforts of a water users' organization at the tank level and the cooperation of private well owners.

No strategies were developed by farmers in the two new tanks, 5 and 6, to supplement inadequate supplies. The main reason is that in these two tanks, only 58 and 21 percent of the target area is actually irrigated. This gap was caused by faulty technical design of the tank sluices. The upper sluices were located below the land to be irrigated.

In the case of Tank 10, farmers should be able to refill the tanks whenever the tank water supplies are low. Yet, even with frequent fillings, the tank supplies were not adequate. This is mainly due to heavy encroachment in the tank foreshore area and the unlawful release of the tank water during the night by encroachers (see Figure 1). This conflict in interest between tank irrigated farmers and encroachers prevents the normal tank operations and causes water shortages.

The success of the strategies adopted by the farmers was directly related to the size of their investments in obtaining adequate supplies.

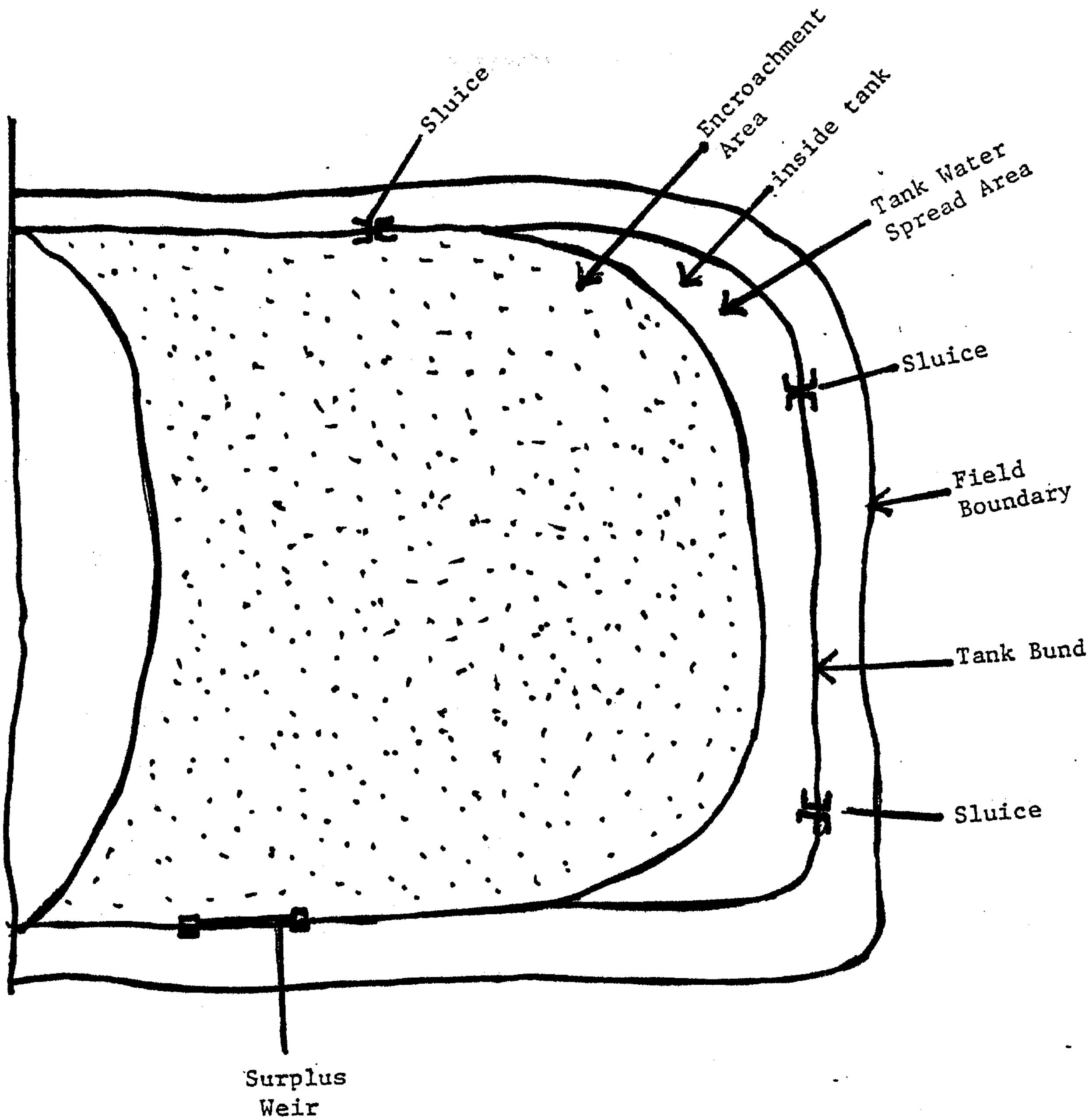

FIGURE 1. Tank with Severe Encroachment.

Farmers in tanks with low water supplies developed a more centralized decision making process to achieve improved water management. This supports the notion that water scarcity encourages farmer cooperation and substitution of management inputs for scarce water.

In three of the tanks, significant efforts were made to substitute management for scarce water as shown by their expenditures on management (see Table 3). The amount spent per acre on management was highest in Tanks 1, 4, and 9 (Rs 9.8, 4.7, and 7.4, respectively). The net benefits due to additional irrigations were also high in these tanks. The net benefits per acre ranged from Rs 43 in Tank 4 to Rs 73 in Tank 9. The expenditures by Tanks 7 and 8 were mostly to obtain additional supplies from the Pilavakal Dam. Their returns were low because they did not adequately manage the supplies they received.[4/]

An important factor encouraging farmer cooperation in the acquisi- and distribution of water is the homogeneity of farms. The greater the variation in farm size, the more difficult it was for farmers to organize and manage the distribution of tank water. Tanks 1, 4, and 9 had the

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[4/] In the case of Tanks 2, 3, 5, 6, and 10, the cost of management per acre was low which results in no measurable benefits. This is because Tank 2 and Tank 3 are dependent tanks and had adequate supplies in 1981-82. The small amount spent was a routine payment to the watermen. They are paid whether or not their services are required. In the case of the newly constructed Tanks 5 and 6, the smaller amount was spent on forming channels to deliver water to the higher elevation fields. The water did not actually reach these fields, hence, there was no benefit from this investment. Unless the upper sluices are relocated, it will be difficult to deliver water to the higher fields. In the case of Tank 10, the amount spent was contributed by rich farmers to hire laborers to do the diversion from the Vaigai Canal. The water diverted was distributed unevenly among farmers. Those near the sluices obtained eight irrigations while farmers at the edge of the command area received two irrigations.

TABLE 3. Return to Water Management Expenditure, 1982.

Tank	Water supply level	Total amount spent on management (Rs)	Amount spent per acre (Rs)	No. of additional tank irrigations per acre due to management	Value of additional irrigations per acre (Rs)[c]	Net benefit per acre due to additional irrigations (Rs)
1	Low	9,720	9.8	4	80	70
2	High	230	0.3	-	-	-
3	High	316	0.2	-	-	-
4	Low	5,462	4.7	2	48	43
5	High[d]	78	0.4	-	-	-
6	High[d]	114	0.5	-	-	-
7	Low	872[a]	2.2	1	16	14
8	Low	355[a]	2.7	1	18	15
9	Low	637	7.4	5	80	73
10	Medium	168[b]	1.8	2-8	50-200	48-198

[a] Amount spent was mainly for making representations to government for additional supplies as specified in previous agreements.

[b] This tank had water rights from Vaigai channel and the amount spent was just to divert the available water. Hence, the net benefit does not just reflect management investment.

[c] Value of additional irrigations per acre equals the cost of pumping water.

[d] High for only the portion being irrigated which is substantially less than the area planned for irrigation.

lowest coefficient of farm size variation, 31, 24, and 33 percent, respectively (see Table 4). Tank 10, which had the most management problems, had the highest variation (104 percent). Tanks 2 and 3 had abundant water supplies and relatively low variation in farm size.

The varying water supply has direct impact on crop production. As the ultimate aim of improving the tank is increased crop production and farm income, it is important to estimate the impacts on crop production of varying water levels. If more water offers large increases in production and income, then a wider range of investments to improve tank irrigation become feasible.

Yield Response to Water

The rice yield response is estimated based on a random sample of 200 farmers irrigated by the ten tanks. A Cobb-Douglas production function is estimated including dummy variables for many of the water management problems. An attempt is made to account for the quantity of water applied, the timeliness of the application and the predictability of water supply. In addition, well water and tank water are separated into two variables. Because of intercorrelation between land, fertilizer and labor, a per acre production function is used.

The Model

The Cobb-Douglas production function has provided a good fit to production data in other studies of agriculture in India. This function form is also less complicated when fitting a function with a large number of independent variables. Finally, no restriction is imposed on the degree of returns to scale. The empirical model is as follows:

TABLE 4. Average Farm Size and Coefficient of Variation for Farm Size.

Tank Number	Tanks	Average Farm Size (acres)	Coefficient of Variation (percent)
1	Srivilliputhur Tank	2.01	31
2	Watrap Big Tank	3.09	66
3	Piramanur Tank	2.45	51
4	Rangian Tank	1.32	24
5	Ramalingapuram Tank	1.98	86
6	Palavanatham Tank	2.01	67
7	Nathampatty Tank	1.90	72
8	Medankulam Tank	1.94	91
9	Teli	1.11	33
10	Thuthai	2.27	104

$$Y = a(TW)^{B_1} (WW)^{B_2} (CL)^{B_3} (F)^{B_4} (A)^{B_5} (CI)^{B_6} e^{B_7(TT)} e^{B_8(EN)}$$

$$e^{B_9(WO)} e^{B_{10}(CS)} e^{B_{11}(S)} e^{B_{12}(TR)}$$

where Y = paddy yield in kgs per acre

TW = tank water used in acre inches per acre

WW = well water used in acre inches per acre

CL = casual labor used in man days per acre

F = fertilizer used in rupees per acre

A = asset value of the farmer in rupees

CI = cultural (management) index of the farmer

TT = tank type, 0 if independent tank
1 if dependent tank

EN = encroachment in the tank, 0 if no encroachment
1 if encroachment

WO = water users' organization, 1 if organization present
0 if no organization

CS = channel structures, 1 if structures are satisfactory
0 if no structure (or) not satisfactory

S = sluice location, 1 for upper sluices
0 for lower sluices

TR = tank rehabilitation measures, 0 if not rehabilitated
1 if rehabilitated

$a, B_1, \ldots, B_{12}$ = parameters to be estimated.

Results

Most of the explanatory variables were statistically significant and the coefficients were relatively high for tank and well water (see Table 5). The high $\bar{R}^2$ indicates that the model explains most of the variation in yield. The only surprises are the low coefficient for fertilizer and the insignificance of water users' organization. The comparison of the marginal value

TABLE 5. Regression of Rice Yield on Inputs and Tank Characteristics, 1982.

Variables	Complete Model		Final Model	
	Coefficients	T-value	Coefficients	T-value
Tank water	0.600	13.04***	0.600	13.04***
Well water	0.376	13.92***	0.374	13.85***
Fertilizer	0.010	3.33***	0.010	3.33***
Casual labor	0.097	4.22***	0.093	4.23***
Asset	0.043	1.43	0.032	1.23
Cultural index	-0.034	0.69	-	-
Encroachment	-0.124	2.53***	-0.126	2.57***
Sluice location	-0.215	3.36***	-0.217	3.39***
Water user organizations	0.022	0.36	0.021	0.34
Channel Structures	0.050	1.04	0.049	1.02
Rehabilitation	0.184	2.33**	0.183	2.32**
Tank type	0.148	2.51***	0.140	2.37**
Constant	-0.391	1.70	-0.385	1.67*
	$\bar{R}^2$ = 0.98		$\bar{R}^2$ = 0.98	
	F = 865.92		F = 947.26	
	N = 200		N = 200	

*** Significant at 1 percent level.

** Significant at 5 percent level.

* Significant at 10 percent level.

products (MVP) and costs of inputs indicated that both the tank and well water were underused, fertilizer overused, and the labor used was about at optimum level (see Table 6). This highlights the importance of water supplies as the major constraint to increasing rice production. Most of the tank level variables, introduced as dummy variables, were also significant. Regardless of the level at which various inputs are applied, the dependent tanks (tank type) have a 13 percent higher rice yield, rehabilitation increases the rice yield by 17 percent, upper sluice location results in a 24 percent reduction in rice yield and encroachment reduces the rice yield by 14 percent.

What alternatives are available to increase tank water supplies? The tank water supply can be increased by reducing the encroachment in the tank foreshore area, reallocation of water among tanks and diverting added rainfall into tanks (water harvesting). However, some of these alternatives will be difficult to implement because of socio-political or physical constraints.

In contrast, a number of rehabilitation alternatives can be implemented fairly quickly in a limited number of tanks. Two types of rehabilitational measures, i.e., lining the main canal and community wells, have been introduced to increase the effective water supply in a few tanks. Both offer good real rates of return on investment (see Table 7).[5/] The dilemma is to introduct the appropriate rehabilitation measures on a large scale and to select the tanks best suited for such investments. A sizeable variation in

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[5/] K. Palanisami and K. William Easter, 1983, The Tanks of South India: A Potential for Future Expansion in Irrigation, Economic Report ER83-4, Department of Agricultural and Applied Economics, University of Minnesota, St. Paul.

TABLE 6. The Marginal Value Products and Price or Costs of Inputs, 1982.

Input	Unit	Marginal Value Product (MVP) (Rs)	Price or Costs (C) (Rs)	Ratio of MVP to C
Tank Water	acre inch	30.36	1.94	15.65
Casual Labor	man day	4.45	5.67	0.79
Fertilizer Use	rupee	0.04	1.06	0.04
Well Water	acre inch	61.08	9.50[a]	6.43
		61.08	12.00[b]	5.09
		61.08	4.50[c]	13.47

[a] Price of water from electric powered private wells.
[b] Price of water from diesel powered private wells.
[c] Price of water from electric powered community wells.

TABLE 7. Internal Rates of Return (IRR) from Tank Rehabilitation, 1982.

Project Life (years)	Community Well	Canal Lining
	---------------- percent	--------------
5	-9.7[a]	14.3
10	12.7	20.5
15	17.1	23.9

[a] Community wells under most conditions will be in use for at least ten years. Thus, the negative return is not very likely.

in farm size, strong private groups of well owners, and encroachment in the tank foreshore are factors which are likely to make rehabilitation difficult and unproductive.[6/] It is important to isolate those tanks which offer the best opportunity for rehabilitation.

Tank Rehabilitation

To develop a criteria for selecting tanks to rehabilitate, the first step is to identify which factors influence tank performance. Since there are a large number of tanks, the identification needs to be done without the benefit of a detailed study of each tank. A number of factors which influence tank performance have been tested in our analysis of ten tanks or suggested by other studies including: farm size variation, water use organizations, the number of private wells, the depth of water in the tank, encroachment, tank type, tank size, location of tank, age of tank, rainfall, expenditure on tank maintenance, and water stored. The next step is to determine which of the above factors are the most important in determining tank performance. To do this, one must select some measure of performance. Von Oppen and Rao (1980) used actual area irrigated in their calculation of economic performance for tanks in semi-arid India. Lenton (1982) suggests four possible measures of irrigation performance: actual area irrigated, water delivery (quantity and timing), crop yield, and variation in the three above measures over time. Given the data available and the fact that the main purpose of the analysis is to select tanks for rehabilitation, a five-year average of the ratio of area irrigated to total command area (actual utilization) is used as the measure of tank performance.

[6/] For more details, see K. Palanisami and K. William Easter, Ibid.

To test the effect of various factors on tank performance, 41 tanks of varying size and type were selected at random in Ramanathapuram District of Tamil Nadu State during 1983. The ten tanks from the 1981-82 tank study were also included to make the total 51.[7/] The location of the tanks are given in Figure 2. Data regarding the tank characteristics such as well numbers, capacity of tanks, expenditures in tanks, location of tanks, etc., were collected from the Irrigation Department, Revenue Department, and from a farmer survey. The relationship between the actual command area utilization and the independent variables was analyzed with a linear regression analysis since scatter diagrams showed a linear relationship between the dependent and independent variables (see Appendix Figure 1). The model is given below (for more information concerning the variables, see the Appendix).

The Model

AU = f (RF, TS, TT, EN, TA, TL, DW, EX, WS, FV, WO, PW)

where:

AU = average actual utilization measured as the ratio of the area irrigated to total tank command area for 1978-82

RF = average annual rainfall in mm for 1978-82

TS = size of tank command area in acres

TT = tank type, 0 independent tanks
1 dependent tanks

EN = tank encroachment in percent of foreshore area

[7/] However, in the final analysis, only 48 tanks were included because three tanks behaved differently from the rest of the tanks. These three were considered outliers and omitted from the analysis. Tank 6 from the ten-tank sample and two tanks from the 41-tank sample were dropped from the analysis.

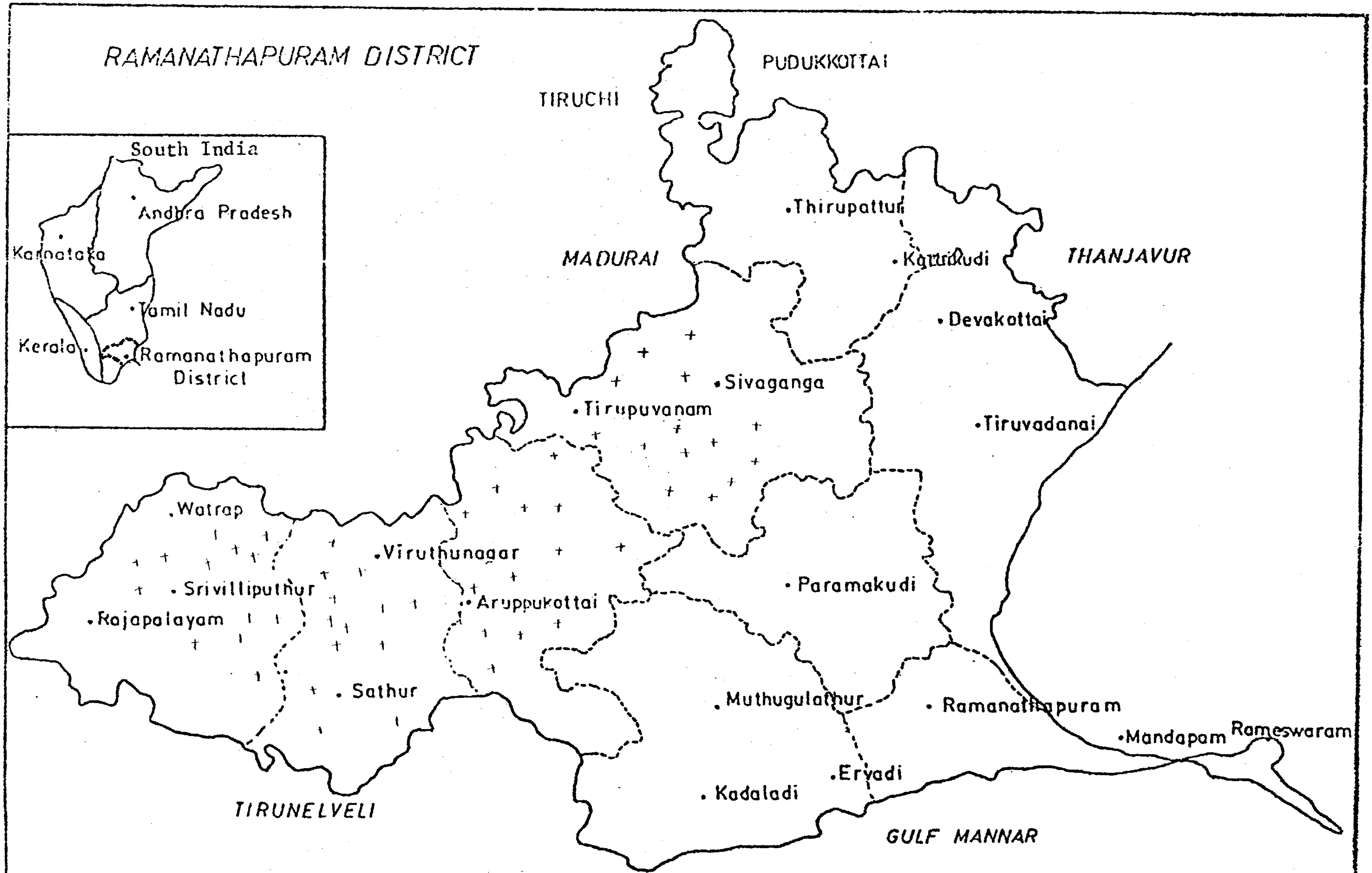

FIGURE 2: Location of Selected Tanks.

NOTE: The + denotes tanks selected.

TA = age of tank, 0 for tanks built in the past ten years
1 for tanks over 50 years old

TL = tank location, 1 for tanks in favorable locations
0 for others

DW = depth of tank water in meters

EX = expenditure on tanks in rupees per acre during 1970-81

WS = water stored per acre of command area in mcft

FV = farm size variation in percent

WO = water users' organization, 1 if organization present
0 otherwise

PW = number of private wells per acre of command area

Results

Six of the 12 variables were significant in explaining differences in tank performance (see Table 8). The $\bar{R}^2$ is 81 percent, indicating that much of the variation in actual tank utilization is explained by the variables considered. Depth of water, farm size variation, encroachment, tank size, tank location and private wells are the significant variables. The variable water users' organization (WUO) is not significant which might be explained by the intercorrelation between WUO and encroachment, farm size variation, tank location, and depth of water (see Table 9). The WUO has high negative correlation with encroachment and high positive correlations with depth of water and location. The tank type has an unexpected sign but is not significant. Other variables, such as age of tank, rainfall, expenditure per acre, and water stored per acre have positive signs as expected but are not significant. The low variation in many of these variables among tanks probably accounts for their not being significant. The coefficients of variation were 21, 27, 18, 23, and 29, for tank type,

TABLE 8. Regression of Tank Utilization on Factors Influencing Performance, 1983.

Variables	Final Model Coefficient	Final Model T-value	Complete Model Coefficient	Complete Model T-value
Depth of Water	.041537	3.147***	.044390	3.066***
Farm Size Variation	-.002090	2.719***	-.002084	2.186**
Encroachment	-.006858	5.345***	-.006639	4.383***
Tank Type	--	--	.049573	1.170
Total Area (Tank Size)	-.000078	2.564***	-.000073	2.294**
Location	.056005	2.134**	.069033	2.308**
Age of Tank	--	--	.003660	0.151
Rainfall	--	--	.000019	0.845
Water Users' Organization	--	--	.017827	0.504
Expenditure/Acre	--	--	.000040	0.890
Water Stored/Acre	--	--	.150905	0.786
Wells/Acre	-.416067	1.852**	-.556341	2.165**
Constant	.922633	11.436***	.876333	8.741***
$\bar{R}^2$		0.82		0.81
F		37.50***		18.06***
N		48		48

*** Significant at 1 percent level.

** Significant at 5 percent level.

* Significant at 10 percent level.

TABLE 9. Correlation Matrix

	Depth of Water	Farm Size Variation	Encroachment	Tank Type	Total Area (Tank Size)	Location	Age of Tank	Rainfall	Water Users' Organization	Expen- diture /Acre	Water Stored /Acre	Wells /Acre
Actual Utilization	0.72	-0.58	-0.80	-0.15	-0.25	0.56	0.13	0.10	0.62	0.26	0.14	-0.23
Depth of Water		-0.41	-0.56	-0.12	-0.13	0.36	0.01	-0.01	0.57	0.10	0.06	-0.24
Farm Size Variation			0.34	0.06	0.20	-0.14	-0.19	-0.15	-0.52	-0.15	0.16	0.39
Encroachment				0.26	0.06	-0.60	-0.10	-0.05	-0.60	-0.16	-0.35	0.02
Tank Type					0.26	-0.22	-0.03	-0.07	-0.22	0.07	-0.13	0.30
Total Area (Tank Size)						-0.05	-0.01	-0.06	-0.05	-0.14	0.12	-0.19
Location							0.01	-0.05	0.54	0.21	0.14	0.13
Age of Tank								0.22	-0.09	0.01	-0.04	-0.09
Rainfall									-0.04	-0.11	0.04	0.04
Water Users' Organization										0.06	0.13	-0.13
Expenditure/Acre											-0.21	-0.03
Water Stored/Acre												0.24

age of tank, rainfall, expenditure per acre, and water stored per acre.

By increasing the water depth by one meter, it is possible to increase the utilization by 4.4 percent, other things constant. Similarly, a reduction in heterogenity of farms by 10 percent will increase the utilization by 2 percent while reducing encroachment by 10 percent will increase the utilization by about 6 percent. A reduction in tank size by 100 acres would increase utilization by only 1 percent. A favorable location increases utilization by 7 percent. A 10 percent increase in the number of wells developed in the command area will reduce tank utilization by about 5.5 percent.

Farm size variation is an important determinant of farmer cooperation, which is necessary for tank maintenance and improved water allocation. Encroachment is encouraged by greater differences among farmers served by a tank. In tanks with high encroachment, farmer cooperation and improved management is impossible because of the acute conflicts between command area farmers and encroachers.

The depth of water variable suggests that siltation is an important problem in many tanks. The tanks which have below normal depth are those which have been silted up. Also, higher tank depth indicates that the tanks will have shorter and higher levees. Normally shallow tanks have longer levees and require greater investment for repairs.[8/]

[8/] Von Oppen and Subba Rao estimated the relationship between cost of bund per length of bund, and length of bund per settled command area. On average, the cost of the bund constitutes 57 percent of the total cost of tank construction. M. von Oppen and K. V. Subba Rao, 1980, Tank Irrigation in Semi-arid Tropical India, Part II; Technical Features and Economic Performance, ICRISAT, Hyderabad, India.

Tank size normally affects the tank utilization in two ways. First, larger tanks have a larger command area and upper and lower sluice differences. The lands under the upper sluices usually do not get adequate water except in good rainfall years. Second, as tank size increases, there is a higher probability of heterogenous farms. Hence, smaller or medium tanks offer greater potential for increasing production through tank improvement. Tank location normally means that additional supplies can be obtained from other tanks as well as from small streams and rivers. Hence, favorable geographic location of tanks is important to the success of a tank.

Private wells are concentrated in the independent tanks. Since independent tanks do not receive adequate supplies, even in normal rainfall years, they need well water in the later crop stages when the tank water is gone. The annual increase in private wells in each tank is between 3 and 10 percent. The sale of well water is becoming an increased source of income for selected farmers. As the dependency on well water increases, the dependency on tank water and tank management decreases. This could result in inequitable tank water distribution and a decline in tank maintenance. At some point this decline in tank maintenance may begin to reduce groundwater supplies since tank water recharges the groundwater. Most independent tanks depend on wells for 30 to 50 percent of their irrigation needs. Institutions of well owners are very strong and have set the price of well water and are influential in tank management.[9/] Thus, in contrast

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9/ For more detail on this see V. Rajagopalan, 1982, "Changing Role of Rural Institutions for Management of Tank Irrigation Systems," paper presented at the Workshop on Modernization of Tank Irrigation: Problems and Issues, Center for Water Resources, Madras.

to our earlier hypothesis, we find that wells have a negative effect on the performance of tanks.

Tank Selection

The magnitude of the variables influencing tank performance will vary from tank to tank. For example, in one tank encroachment may be high and in another tank farm size variation may be high. Hence, different weights are given to each variable according to their magnitude in each tank. The cumulative value for each tank is then used to identify tanks for rehabilitation.[10/]

Weights

Two alternative weights are assigned to each of the six significant variables (see Table 10). The weights for positive characteristics are given greater weight in the second alternative. For example, in Alternative I, favorable farm size (i.e., 0 to 100 acres) is given a weight of 3, while in Alternative II, it has a weight of 4. The cumulative value for each tank is determined by summing the weighted values of the six variables. The cumulative values are called the Tank Rehabilitation Index (TRI).

The TRI should give the highest number to those tanks best suited for rehabilitation. The tanks are arranged in descending order with the

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[10/] Tank rehabilitation refers to a wide range of investments both in physical and human capital. The investment may be either above the outlet such as increasing the tank storage capacity or below the outlet such as reducing water losses in the canals. The investment may also be in helping organize farmers to allocate water or maintain the system. The specific type of investment will have to vary from tank to tank depending on the exact nature of the water problems.

TABLE 10. Tank Performance Variables with Relative Weights.

Variables	Range of Variables	Alternative Weights I	Alternative Weights II
Tank Size	0-100 acres	3	4
	101-400 acres	2	2
	> 400 acres	1	1
Tank Location	Favorable	2	3
	Others	1	1
Wells Per Acre	0-0.05	3	4
	0.06-0.10	2	3
	> 0.10	1	1
Encroachment	0-10 percent	3	4
	11-25 percent	2	2
	> 25 percent	1	1
Depth of Water	0-2.0 meters	1	1
	2.1-4.0 meters	2	2
	> 4.0 meters	3	4
Farm Size Variation	0-30 percent	3	4
	31-50 percent	2	2
	> 50 percent	1	1

tank having the highest TRI first (see Table 11). However, it is not clear which of the two weights gives the "best" ranking. To determine which weights provide the "best" priority, the ten tanks from the 1981-82 sample are ranked based on what we found in our detailed study of these tanks (Palanisami and Easter, 1983). Nine out of the ten tanks are ranked as follows:[11/] 9, 4, 1, 3, 7, 5, 2, 8, 10. The two alternative TRI's rank the ten tanks in much the same manner.[12/] Alternative II puts the tanks in four distinct groups but does not differentiate between the tanks in each group (see Table 12). Alternative I spreads out tanks a little more but still does not differentiate between two groups. However, this may be all one can expect from such a criteria. What is needed is some method to identify the best tanks for rehabilitation without doing a benefit-cost analysis of each. It does not matter whether Tank 9 or 4 is improved first. The important thing is to identify them as high priority and not Tanks 8 and 10.

Tank Priority

Tanks are now grouped into four priority ranges (high, intermediate, low, and very low) for rehabilitation. A comparison is then made between the two alternative weights and the ranking provided by the earlier study

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[11/] Tank 6 was not included in the analysis due to its extreme variation in area irrigated because of faulty design of the sluices. This is one of the new tanks where only 21 percent of the target area was irrigated.

[12/] Our ranking was done giving importance to crop yield, net return to water management, presence of WUO, and potential yield increase, in addition to the six variables considered in the model. Our close observation of these nine tanks, as well as the engineer's opinion, helped finalize the ranking.

TABLE 11. Listing of Tanks for Rehabilitation.

Ranks	Alternative Weights I	Alternative Weights II
	-- tank numbers --	
1	22	22
2	20	20
3	48	48
4	41	11
5	46	46
6	47	47
7	11	41
8	19	19
9	35	35
10	9	29
11	29	4
12	30	9
13	42	30
14	43	42
15	15	15
16	18	18
17	24	24
18	27	43
19	1	23
20	4	27
21	21	28
22	23	33
23	28	37
24	31	1
25	33	3
26	37	7
27	3	16
28	16	21
29	17	31
30	25	17
31	32	25
32	36	32
33	2	34
34	5	36
35	7	5
36	49	2
37	12	13
38	13	39
39	26	40
40	34	44
41	39	49
42	40	12
43	8	26
44	44	8
45	14	10
46	10	14
47	45	45
48	38	38

TABLE 12. Tank Rehabilitation Index (TRI) for Ten-Tank Sample.

TRI Alternative I	Tank Number	TRI Alternative II	Tank Number
8	10	9	8,10
9	8	10	--
10	2,5,7	11	2,5
11	3	12	--
12	1,4	13	1,3,7
13	--	14	--
14	9	15	--
		16	4,9

TABLE 13. Ranking of Ten Tanks by Priority.

Priority	1982 Study	Alternative I	Alternative II
High	9,4,1	9	9,4
Intermediate	7	4,1	1,3,7
Low	2,3,5,8	3,7,5,2	2,5
Very Low	10	10,8	8,10

(see Table 13). We ranked Tank 9 as high priority because it is a small tank and farmers are very cooperative and willing to make investment in water management. The two big tanks, 4 and 1, are also ranked high priority because both have effective WUO and invest in water management practices. Tanks 2, 3, 5, and 8 were listed as low priority because Tanks 2 and 3 are dependent tanks and have adequate supplies in most years. There is no immediate need for rehabilitation but there may be possibilities for increased water use efficiency, provided the water saved by conservation can be diverted to other tanks. Tanks 7 and 8 are part of a system of tanks and the major problem is that of relaxing the barriers to obtaining water from a large upstream dam. Once this is done, then these tanks would be ready for rehabilitation. However, Tank 7 is ranked higher than Tank 8 because it is near the large dam and is more likely to receive water supplies in the future. Tank 5 is a new tank and its problems are related to poor design. Tank 10 is listed under very low priority due to its perennial conflicts among farmers. This is the tank which has serious encroachment and irrigates very little land with abundant tank water supplies. Permanent improvements are currently impossible because encroachers can block any efforts towards tank improvement.

The priorities found by using the two alternative TRI's are quite similar to that found in our more detailed analysis. Tank 3 ranks higher under Alternative II, primarily because it was just recently improved and the effects are not picked up in our five-year average of area irrigated. The only other problem is that Tanks 4 and 7 are ranked lower under Alternative I while Tanks 1 and 8 are ranked lower under both alternatives. This points out that one must use the ranking system with some caution. It cannot be expected to differentiate among tanks that are quite similar in characteristics.

The Irrigation Department should use the criteria as a starting point for selecting tanks for rehabilitation. The high priority group should be addressed first followed by those in the intermediate priority group. Many tanks in the low priority group would be difficult to improve, unless some major changes occur. Tanks in the very low priority group are probably beyond help unless some strong institutional help is provided to eliminate the social and/or physical constraints to development. This is true of Tank 10 and possibly Tank 8. Yet, final decisions concerning whether or not to invest in a tank should not be made without an on-site visit and more detailed analysis of the top priority tanks.

The next question, after ranking tanks, would be how many tanks should be selected at one time for rehabilitation. This depends on the budget allocation by the government to the Public Works Department (PWD) for tank rehabilitation as well as fund disbursement by PWD for individual sections.[13/] Normally, the budget is allotted every year by the PWD for individual sections for tank repairs. It is the responsibility of the section engineers to select the priority tanks for investment and the TRI's should be a useful guide.

The ranking of the 48 tanks is shown in Table 14. The PWD has 10 to 12 tanks from which to select as high priority tanks for rehabilitation. In this selection it would appear that Tanks 20, 22, and 48 should be

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[13/] A section is the last administrative unit of the PWD where a junior engineer or assistant engineer controls about 40 to 50 tanks.

TABLE 14. Tank Priority for Rehabilitation.

Priority[a]	Tank Numbers Alternative I	Total	Alternative II	Total
Very Low	8, 10, 12, 13, 14, 26, 34, 38, 39, 40, 44, 45, 49	13	8, 10, 12, 14, 26, 38, 44, 45, 49	9
Low	2, 3, 5, 7, 16, 17, 21, 23, 25, 28, 31, 32, 33, 36, 37	15	2, 5, 13, 16, 17, 21, 25, 31, 32, 34, 36, 39, 40	13
Intermediate	1, 4, 15, 18, 24, 27, 29, 30, 42, 43	10	1, 3, 7, 15, 18, 23, 24, 27, 28, 30, 33, 37, 42, 43	14
High	9, 11, 19, 20, 22, 35, 41, 46, 47, 48	10	4, 9, 11, 19, 20, 22, 29, 35, 41, 46, 47, 48	12

a/ The ranges in TRI used for the priority classification are the following:

Alternative I: TRI 7-9 = very low; 10-11 = low; 12-13 = intermediate; and 14 and above = high.

Alternative II: TRI 7-9 = very low; 10-12 = low; 13-15 = intermediate; and 16 and above = high.

given highest priority because of their high TRI's while, of the tanks we studied in detail, Tank 9 stands out as top priority.

Conclusion

In conclusion, production in the tank irrigation areas is heavily constrained by water inadequacy. This is further complicated by encroachment, silting of tanks, and poor tank maintenance. Rehabilitation of these tanks to increase water supplies and production should be pursued on a large number of these tanks. Measures such as canal lining and community wells have already proven feasible on a small sample of tanks. The benefits of such improvement can approach the difference in crop output between dependent and independent tanks.

The methodology suggested to select tanks for rehabilitation is a preliminary one. Further research is needed to concentrate on the behavior of the different tanks under varying socioeconomic conditions over time, particularly under varying rainfall levels. It is equally important to find ways to reduce or eliminate encroachment and foster cooperation among farmers.

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APPENDIX

Where AU = actual utilization, which is the measure of the tank performance. It is calculated as the ratio of the actual area irrigated to total command area for each tank. It is the average figure for the last five years, 1978-82.

RF = the average annual rainfall of the last five years, 1978-82, for the particular tank location in mm. As rainfall increases, the actual utilization should increase. $\frac{\partial AU}{\partial RF} > 0$

TS = size of tank, measured in terms of total tank command area in acres. It is hypothesized that as the size of tank becomes larger, the utilization will be lower, because of the problems in water storage and distribution. $\frac{\partial AU}{\partial TS} < 0$

TT = tank type, measured as a dummy variable, with 1 for dependent tanks and 0 for independent tanks. Dependent tanks should have higher utilization than independent tanks. $\frac{\partial AU}{\partial TT} > 0$

EN = encroachment in the tank foreshore. It is measured as the percent of the foreshore area encroached on by farmers for crop cultivation. As the encroachment increases the utilization is reduced, due to low water storage in the tank. $\frac{\partial AU}{\partial EN} < 0$

TA = age of tank, measured as a dummy variable, with 1 for tanks over 50 years old and 0 for tanks built in the past 10 years. It is observed from previous studies that the performance of the recently constructed tanks was comparatively poor. Hence, it is hypothesized that old tanks have higher utilization. $\frac{\partial AU}{\partial TA} > 0$

TL = tank location, measured with a dummy variable where 1 is for tanks favorably located to receive runoff water and additional supplies from adjacent tanks, and 0 for others. It is expected that tanks in favorable locations have higher utilization. $\frac{\partial AU}{\partial TL} > 0$

DW = depth of tank water, in meters. The depth of water indicates the relative storage position of different tanks. It is hypothesized that as depth increases, the storage will be more stable and the area irrigated will increase. $\frac{\partial AU}{\partial DW} > 0$

EX = expenditure per acre on tanks in rupees during 1970-81. This measures the expenditure made on repairs and other tank improvements. The higher the expenditure, the greater will be the tank improvements and performance. $\frac{\partial AU}{\partial EX} > 0$

WS = water stored per acre in the tank in mcft. It is the capacity of the tank times the number of fillings divided by total command area. Some tanks have greater capacity but receive only one filling while others have a lower capacity and receive several fillings. The more water stored per acre in the tank, the better the tank performance. $\frac{\partial AU}{\partial WS} > 0$

FV = farm size variation measured with the coefficient of variation for farm size expressed as a percentage. Higher farm size variation is an indication of heterogeneity among farms which results in poor tank management. $\frac{\partial AU}{\partial FV} < 0$

WO = water users' organization is introduced as a dummy variable, where 1 is used if an organization exists and 0 if not. It is hypothesized that WUO will promote higher tank utilization. $\frac{\partial AU}{\partial WO} > 0$

PW = number of private wells available per acre of command area.

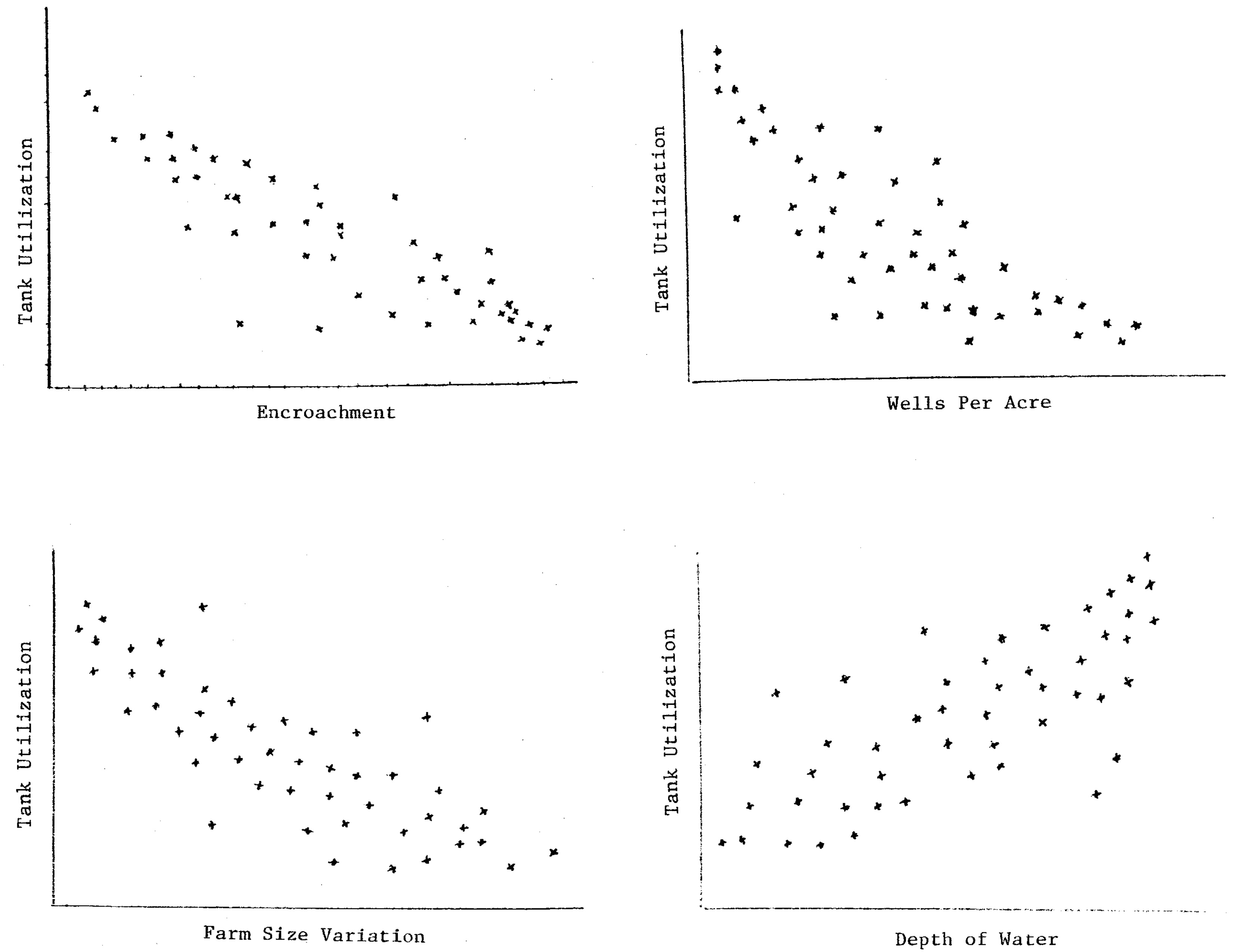
As the number of private wells increase to supplement tank water, there is more potential for increasing the area cropped. $\frac{\partial AU}{\partial PW} > 0$

APPENDIX TABLE 1.

Listing of Tanks by Priority by Rehabilitation.

Tank Number	Alternative Weights I	Alternative Weights II
	-- tank performance index --	
1	12	13
2	10	11
3	11	13
4	12	16
5	10	11
7	10	13
8	9	9
9	14	16
10	8	9
11	14	18
12	9	9
13	9	10
14	8	8
15	12	14
16	10	12
17	10	11
18	12	14
19	14	17
20	16	20
21	11	12
22	17	22
23	11	13
24	12	14
25	10	11
26	9	9
27	12	13
28	11	13
29	13	16
30	13	15
31	11	12
32	10	11
33	11	13
34	9	11
35	14	17
36	10	11
37	11	13
38	7	7
39	9	10
40	9	10
41	14	18
42	12	14
43	12	13
44	8	9
45	7	7
46	14	18
47	14	18
48	15	19
49	9	9

NOTE: Because of the deletion of Tank 6, the Tank Number 6 is not shown.



APPENDIX FIGURE 3. Scatter Diagram Between Tank Utilization and Several Independent Variables.