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THE TANKS OF SOUTH INDIA

(A POTENTIAL FOR FUTURE EXPANSION IN IRRIGATION)

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Glossary:

Tank: An irrigation tank is a small reservoir constructed across the slope of a valley to catch and store water. Generally the tanks have a maximum depth of not more than 15 feet although some are as deep as 25 to 30 feet. Medium-sized tanks have a capacity of up to 100 million cu. ft. with an average depth of 8 to 10 feet. Many tanks form parts of a system of tanks and either receive surplus water from tanks above or discharge surplus water into tanks below or do both.

System tanks: Tanks that receive supplemental water from major streams or reservoirs in addition to the yield of their own catchment area. Generally more than one crop is grown in these tanks.

Non-system tanks: Tanks that depend on the rainfall in their own catchment area and are not connected to major streams, or reservoirs. Usually a single crop is raised in these tanks. These tanks often linked with other rainfed tanks thus forming upper and lower tanks.

Major tanks: Tanks with a command area of more than 200 acres.

Minor tanks: Tanks with a command area of less than 200 acres.

Standardized tanks: Tanks that have been surveyed by the Tank Restoration Scheme (TRS) to fix permanent standards regarding area to be irrigated, tank capacity, location and level of sluices, surplus weirs etc. Normally after standardization these tanks will become the responsibility of the Panchayat union or Public Works Department (PWD).

Ex-zamin tanks: Tanks that are non-standardized.

Panchayat union tanks: Standardized tanks with a command area of less than 100 acres and under the control of local Panchayat unions for operation and maintenance.

PWD tanks: Standardized tanks with a command area of more than 100 acres under the control of Public Works Department (PWD).

Dependent tanks: Tanks that have adequate water supply for at least one crop each year. It is also possible to grow more than one crop in many of these tanks. They generally have a supplemental water source such as a river or a large reservoir.

Independent tanks: Tanks that have inadequate water supply in years of normal or below normal rainfall and depend on ground water to obtain a crop.

Tank sluice: Tank outlet point or openings where the main canal draws water for distribution to the fields. The sluice openings are controlled by gates so that the opening can be adjusted according to demand for irrigation water. The number of sluices in a tank is directly related to the size of the tank and topography of the fields irrigated.

Glossary: (continued)

Tank water spread area: The area that will be flooded when the tank is filled to capacity.

Tank foreshore or Neer Pidippu or Poramboke lands: These lands normally are the ones immediately above tank water spread area. These lands will be submerged only when the tank fills to above normal capacity. Sometimes, these lands include the area left uncultivated for common use such as tree planting and making diversions to carry water from outside sources to the tank. These lands form part of tank water spread area when the tank exceeds normal capacity.

Tank encroachment: Involves the unauthorized cultivation in the tank foreshore lands, and water spread area particularly when the tank is not full. Generally the tanks are not filled to the full capacity and permanent cultivation is practiced in the foreshore lands by farmers. Subsequently the cultivation spreads to the water spread area when the tank water supply recedes. In the long-run this unauthorized cultivation is made permanent and the tank storage capacity is reduced.

Kudimaramathu: Is the cooperative repair work done when each farmer provides labor for maintenance of minor irrigation projects such as tanks.

Local irrigation grant: Is the grant made by the state government to the Panchayat unions to enable them to maintain the standardized tanks under their control. This grant is released every year based on the annual needs of each Panchayat union. These funds can be used to make changes in tank structures such as sluices, weirs, etc.

Minor irrigation grant: Is the grant made to the Panchayt unions by the state government once in every three to five years to maintain the non-standardized tanks under their control. These funds cannot be used to make changes in tank structures.

mil. $ft.^3$ = million cubic feet

1$ = Rs 9.5

Paddy crop = rice crop.

PREFACE

This report is part of the work done by the University of Minnesota and Colorado State University for the U.S Agency for International Development under the Cooperative Agreement for Economic Planning and Policy Analysis of Irrigation. The studies have been concentrated in Asia and North Africa with special emphasis on South India, Northeastern Thailand, Egypt, and Pakistan. The work in Thailand and India is focusing on small scale irrigation while that in Egypt and Pakistan is concerned with large scale projects.

The authors would like to thank Drs. Willis Peterson, Carl Pray and John Waelti for the very helpful comments on an earlier draft of this bulletin. We are also indebted to Drs. Rajagopalan and Sivanappan for their help and encouragement in setting up the study. This study is the result of a long-term collaboration between the Department of Agricultural and Applied Economics at the University of Minnesota and Tamil Nadu Agricultural University.

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CHAPTER I

INTRODUCTION

Irrigation development in India continues to be given a high priority, with full irrigation potential[1/] estimated at about 58 million hectares in 1979-80. This amounts to about 51 percent of the total area of 113.5 million hectares that could be irrigated. Total investment in irrigation from the beginning of the planning era in 1951 to 1978 amounted to approximately 93 billion rupees on major, medium and minor projects (Posz, et.al., 1980). Minor irrigation has contributed over half of the growth in total irrigation potential (see Table 1).

Minor irrigation includes all ground and surface irrigation development projects with command areas of 2000 hectares or less. Groundwater development forms the bulk of the minor irrigation. It is implemented primarily through individual and cooperative efforts with finance help from government sources. The cumulative growth in minor irrigation from surface water sources has been about 1.6 million hectares in a period of 30 years. This is an average annual increase of 0.053 million hectares as compared to 0.516 million hectares per year increase for groundwater irrigation (see Table 2). Major and medium sized projects have added 0.577 million hectares per year to the irrigated area (Venkatesan, 1982).

Minor irrigation schemes from surface water are essentially tank (small reservoir) irrigation. The tanks have existed in India from time immemorial, and have been an important source of irrigation, particularly in southern India. However since 1960-61 the rapid expansion in well irrigation and the poor maintenance of tanks have combined to drop tank irrigation's share of the irrigated area to only 11.6 percent (Table 3).

1/ The irrigation potential is defined as the area that has the possibility of becoming irrigated within existing irrigation facilities.

TABLE 1. Cumulative Growth of Irrigation Potential in India

Plan	Major and Medium Irrigation	Minor Irrigation	Total
	- million hectares -		
Irrigation Potential (1950-51)	9.70	12.90	22.60
First Plan (1951-56)	12.20	14.06	26.26
Second Plan (1956-61)	14.30	14.79	29.09
Third Plan (1961-66)	16.60	17.01	33.61
Annual Plans (1966-69)	18.10	19.00	37.10
Fourth Plan (1969-74)	20.90	23.50	44.40
Fifth Plan (1975-80)	27.02	30.00	57.02

SOURCE: Workshop on Modernization of Tank Irrigation, inaugural address by M. N. Venkatesan, held at Centre for Water Resources, Madras, India, February 10-12, 1982.

TABLE 2. Cumulative Growth of Minor Irrigation Potential in India

Item	1950-51	1960-61	1968-69	1979-80
		- million hectares -		
Surface Water	6.40	6.45	6.50	8.00
Ground Water	6.50	8.34	12.50	22.00
TOTAL	12.90	14.79	19.00	30.00

SOURCE: Workshop on Modernization of Tank Irrigation, inaugural address by M. N. Venkatesan, held at Centre for Water Resources, Madras, India, February 10-12, 1982.

TABLE 3. Area Irrigated by Different Sources in India

Source	1950-51	1960-61	1970-71	1975-76
		- percentages -		
Canals	39.8	42.1	41.3	39.9
Tanks	17.3	18.5	13.2	11.6
Wells	28.7	29.6	38.2	41.6
Others	14.2	9.8	7.3	6.9

SOURCE: Indian Agriculture in Brief, 1978-79.

Although, tank irrigation can be found in all parts of India, they account for over 30 percent of the total irrigation in Andra Pradesh, Karnataka and Tamil Nadu States (Table 4 and Figure 1). Among the States, the percentage of area irrigated by tanks is highest in Tamil Nadu, which shows the importance of tank irrigation in Tamil Nadu State. It is also the State which has utilized about 92 percent of the surface water potential and 70 percent of the groundwater potential (Sakthivadivel et. al. 1982).

The three major sources of irrigation in Tamil Nadu, account for about equal shares of the irrigated area (see Table 5). Almost 48 percent of the total cropland is irrigated in the State compared to 26.5 percent for all India. The average annual rainfall is 950 mm in Tamil Nadu, compared to the all India average of 1200 mm. The rainfall patterns and land distribution play important roles in the economy of the State. Rainfall is much higher in the coastal and mountains areas. The rest of the state has low rainfall particularly the tank irrigated areas.

Marginal holdings (below 1 hectare) and small holdings (between 1 and 2 hectares) constitute about 64.2 and 18.7 percent of total land holdings, compared to all India average of 50.6 and 19.0 percent respectively. The state area cultivated was 20.7 and 20.8 percent respectively for the marginal and small holdings compared to 9.0 and 11.9 percent respectively for all India (Agricultural Census, 1976-77). Most of the marginal and small holdings in the State are concentrated in the tank irrigated areas.

Among the districts in Tamil Nadu State, Ramanathapuram district has the highest concentration of tanks. Out of the total of 39,202 tanks in the State, 26 percent or about 10,208 tanks are in this district (Table 6). Among the three different categories of tanks, Panchayat union tanks, Public Works Department (PWD) tanks and Ex-zamin tanks, PWD and Ex-zamin tanks are the

TABLE 4. Area Irrigated by State in India, 1977-78

State	Area Irrigated by Tanks	Total Area Irrigated	Percent
	-thousand hectares-		
Andra Pradesh	1,027	3,281	31.3
Bihar	82	2,320	3.5
Gujarat	36	1,341	2.7
Karnataka	366	1,201	30.5
Kerala	76	457	16.6
Madya Pradesh	119	1,645	7.2
Maharastra	222	1,472	15.1
Orissa	185	878	21.1
Rajastan	233	2,378	9.8
Tamil Nadu	910	2,836	32.1
Uttar Pradesh	322	7,241	4.4
West Bengal	303	1,489	20.4

SOURCE: Workshop on Modernization of Tank Irrigation, inaugural address by M. N. Venkatesan, held at Centre for Water Resources, Madras, India, February 10-12, 1982.

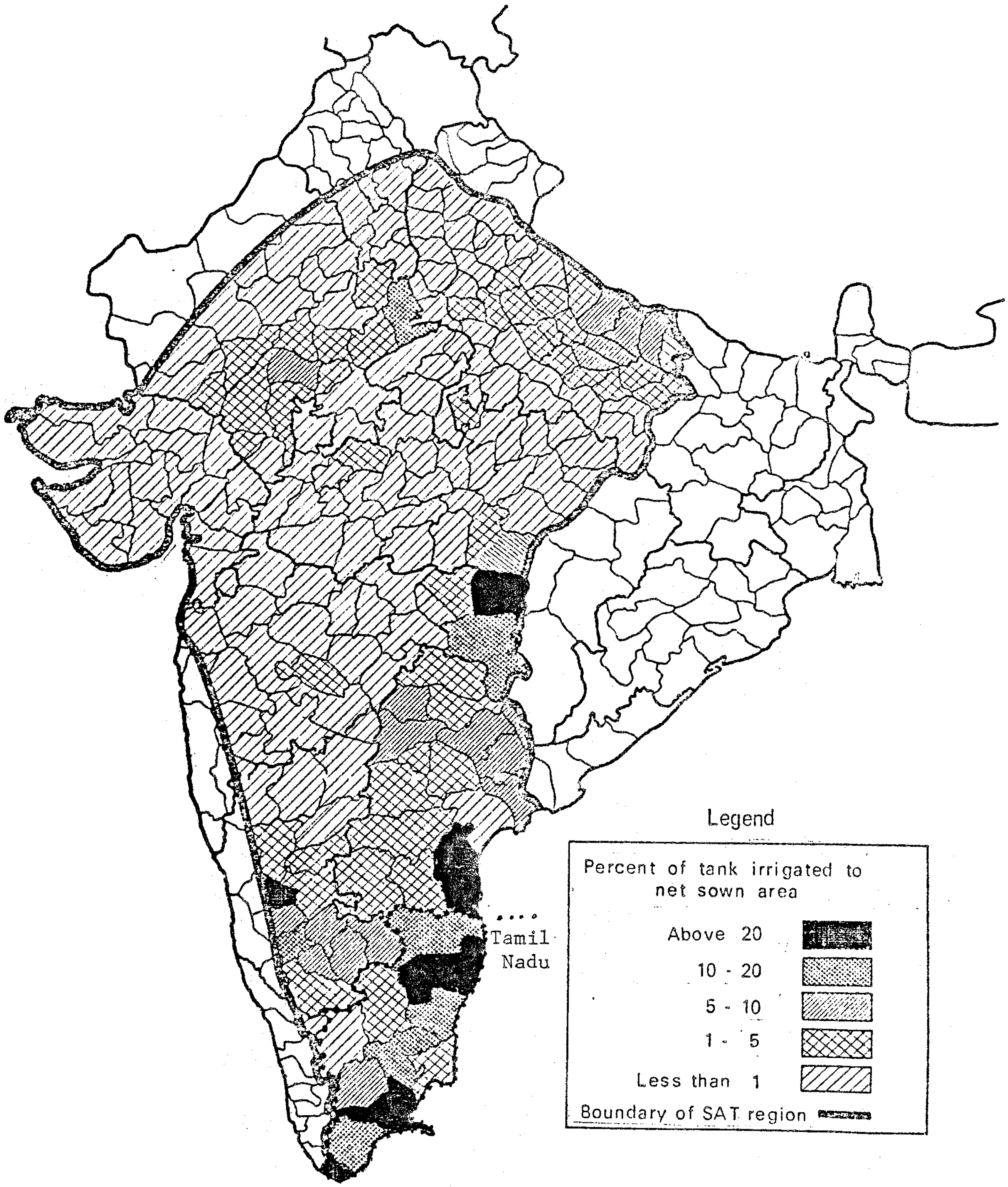

Figure 1. Density of Tank Irrigation in Semi-Arid Tropical (SAT) India

Source: M. Von Oppen and K.V. Subba Rao. Tank Irrigation in Semi-Arid Tropical (SAT) India, ICRISAT, Hyderabad, India, 1980.

TABLE 5. Area Irrigated in Tamil Nadu by Source

Source	1950-51	1960-61	1970-71	1977-78
		- percentages -		
Canals	42.5	35.8	33.9	32.7
Tanks	30.5	38.0	34.5	32.1
Wells	23.0	24.2	29.8	33.8
Others	4.0	2.0	1.8	1.4

SOURCE: Tamil Nadu, An Economic Appraisal, 1979.

Table 6. The Number of Tanks in Tamil Nadu Districts

	Panchayat Union Tanks			PWD Tanks			Ex-Zamin Tanks	
District	Less than 50 acres	From 50 acres to 100 acres	Sub-total	Rainfed tanks more than 100 acres	System tanks*	Sub-total	Total	Grand total
Chengalpattu	1,241	542	1,733	1,202	5	1,207	756	3,746
North Arcot	1,482	602	2,084	632	537	1,169	482	3,735
South Arcot	1,213	553	1,766	573	184	757	79	2,602
Salem	449	100	549	188	6	188	--	737
Dharmapuri	1,451	129	1,579	98	3	101	154	1,834
Coimbatore	42	22	64	57	2	59	--	123
Thanjavur	338	153	491	5	680	685	--	1,176
Pudukkottai }	4,609	725	5,334	369	161	530	58	6,394
Tiruchy }				173	85	268	214	
Madurai	3,142	249	3,391	288	483	771	331	4,493
Ramanathapuram	642	691	1,333	1,378	130	1,508	7,367	10,208
Tirunelveli	806	159	965	289	397	686	445	2,096
Kanyakumari	1,062	12	1,074	24	960	984	--	2,058
Nilgiris	--	--	--	--	--	--	--	--
TOTAL	16,477	3,936	20,413	5,276	3,627	8,903	9,886	39,202

*Includes tanks with ayacut less than 100 acres.

Source: R. Sakthivadivel et al., "A Pilot Project Study of Modernization of Tank Irrigation in Tamil Nadu," Centre for Water Resources, Madras, February 1982.

Note: 1) The Panchayat union tanks are standardized tanks with command area of below 100 acres.
2) The PWD tanks are standardized tanks with command area of above 100 acres.
3) The Ex-Zamin tanks are non-standardized tanks, irrespective of the command area. After standardization these Ex-Zamin tanks will be classified as Panchayat union or PWD tanks based on size of the command area.

largest in number in the district. About 30 percent of the Ex-zamin tanks are system tanks. The possibilities for increasing the water use efficiency in these Ex-zamin tanks is very high. The water problems in this district are also common to tank irrigation in other districts. Thus, Ramanathapuram district provides an ideal setting to study the range of water use problems facing tank irrigation in most of Tamil Nadu.

The Importance of Tank Irrigation

Continued progress in water resources development in the future will depend upon the utilization of the existing irrigation potential. There is a sizable gap between potential irrigation and actual land irrigated due to inefficient water management practices. Rapidly escalating construction costs constitute a growing drain on State finances and increase the already high financial subsidy given to irrigated farms. The unofficial estimates of the total costs of new medium sized surface irrigation projects are from Rs 15,000 to Rs 25,000 per hectare, in real terms, almost double the cost ten years ago (Seckler, 1981). In addition, larger projects benefit only one section of a district or state and are many times limited by physical characteristics, i.e., there are only a limited number of large dam sites.

The distribution and development of groundwater is governed by power and groundwater availability. Rural electrification coupled with an assured supply of electric power is a fundamental requirement for utilization of pump irrigation since electricity provides the lowest cost means (to farmers) of lifting groundwater[2/]. Diesel powered pumps and water lifting devices operated by draft animals tend to be more expensive and cumbersome to operate than electric pumps. The scarcity and resulting rapid increase in diesel fuel prices has slowed

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2/ Electricity is sold to farmers at subsidized rates compared to other uses.

groundwater development and placed higher demands on electricity. With the increasing demand for electric power, the inelastic supply of electricity has constrained groundwater development.

Tank irrigation, in certain parts of India provides a better alternative for irrigation development. Tanks can have a wider geological distribution than large projects. Income distributional and employment generation effects are not limited to one area. Tank investments tend to be less capital intensive and can involve local people in improvement and construction works. Currently the tank irrigation potential is under utilized due to lack of tank management.

Study Plan

The primary concern of this study is the potential for tank modernization and improvement in the southern most state of India, Tamil Nadu. The focus is on the drought prone Ramanathapuram District where there is a large concentration of tanks. A sample of 200 farmers was selected from ten tanks for a detailed analysis of production, input use, water management practices and alternatives for modernization.

We are particularly interested in helping develop a strategy for improving the performance of tank irrigated areas. This will mean finding ways to improve the distribution of water as well as increasing existing supplies. Part of the study will be to find out what farmers are doing to improve water use. Returns will be estimated for alternative strategies based on data collected from the farm surveys.

More specifically we will focus on: (1) the organization and management of tanks, (2) the constraints to better performance of tanks, and (3) the returns from alternative strategies for improving tank performance.

In the analysis we will test the following hypotheses:

(1) Tank water supplies vary according to water source (dependent vs. independent tanks).

(2) Acute conflicts exist between head and tail end farmers; between well owners and other farmers; fishery benefits and irrigation benefits; and encroachers and command area farmers.

(3) Crop yield is influenced by water availability, asset position, labor use, management and fertilizer application.

(4) The encroachment in the tank bed, sluice location in the command area, existence of farmers' organization and condition of channel structures all affect the crop yield.

(5) Tank rehabilitation increases production and income.

CHAPTER II

TANK IRRIGATION IN TAMIL NADU

In spite of the rapid development of industry in recent years, agriculture continues to have a predominant influence on the state's economy. It contributed about 40 percent of state income and employed about 60 percent of the labor force in 1978-79. The total net sown area in Tamil Nadu state is approximately 6.4 million hectares. The major crop of the state is rice and the state ranks second in rice production in India. Rice accounts for about 37 percent of the cropped area and about 80 percent of the state's foodgrain production. Although both the southwest and northeast monsoons bring adequate rain to the state, its occurrence is erratic and unreliable. Three quarters of the state lies in the rain shadow of the Western Ghats and the precipitation in these semi-arid regions varies from 600 to 1000 mm. This unreliable rainfall pattern encouraged the irrigation development of the state.

The Palar and South Ponniar rivers in the northern part of the state, the Cauvery river along with its tributaries Bhavani, Amaravathi and Noyyal in the middle and the Vaigai and Tambaraparani rivers in the south are the major river systems in the state. Canal irrigation which is predominant in Thanjavur district and parts of Coimbatore and Trichirapalli districts presently covers about 0.9 million hectares. With the decline in untapped surface resources and increasing reliance on groundwater the relative share of canal irrigation has declined.

Well irrigation which commanded an area of about 0.40 million hectares in 1950-51 now commands over 0.93 million hectares. Over the last 30 years, increased attention was paid to groundwater development in the state. At present there are about one million wells in operation. The wells are used as a primary source of irrigation as well as for supplementing surface water sources. However, the absence of powerful legal control over installation of wells, has resulted in over-exploitation of groundwater in many locations, resulting in external costs to well owners. The increasing energy cost and the frequent energy shortages is now discouraging investment in wells. In view of the constraints to canal and well irrigation development, the possibility for increasing tank irrigation needs renewed attention.

Tank irrigation systems in Tamil Nadu have been in existence since Vedic times. There are about 39,200 irrigation tanks in the State, irrigating an area of about 0.91 million hectares. A number of tanks with inscriptions dating back a millennium or longer provide evidence that tank irrigation technology of utilizing the surface runoff is deeply rooted in the south Indian irrigation culture. The tanks are concentrated in the districts of Chingleput, North Arcot, South Arcot, Pudukkottai, Ramanathapuram and Tirunelveli.

Classification of Tanks

Tanks are normally classified into system and non-system tanks. System tanks are those which receive water from nearby major streams or reservoirs in addition to water from their catchment. They enable the farmers many times to raise more than one crop. Non-system tanks depend on the rainfall in their own catchment and are not connected to a river system. Usually a single crop is raised under these tanks (Palanisami, 1981). Non-system tanks are often linked with the other tanks thus forming upper and lower tanks. During times of heavy rainfall, the surplus water from upper tank will flow to the lower tanks. In the non-system tanks the command to catchment area ratio will be 1:8 to 1:15 varying from high rainfall areas to lower rainfall areas, where as for system tanks, the ratio will be smaller, 1:2 to 1:5 due to their additional sources of water.

Tanks are also classified based on the size of command area and the nature of control. Normally the tanks after standardization, are classified as major and minor tanks. Major tanks irrigate an area of more than 200 acres and minor tanks irrigate less than 200 acres. However, the maintenance responsibility is based on a different size classification. Tanks irrigating more than 100 acres are the responsibility of the PWD and tanks which irrigate less than 100 acres are under the control of panchayat unions.[1/] The Ex-zamin tanks generally are the non-standardized tanks irrespective of the size of the command area. After standardization the Ex-zamin tanks will be either PWD or panchayat union tanks based on the size of command area. Among the total tanks, about 7,300 irrigate more than 100 acres and about 31,900 less than 100 acres. Thus in numbers the small tanks are the most important to the State.

Origin

Although tank irrigation has existed in India since Vedic times most of the tanks were built about 100 years ago (Von Oppen and Binswanger, 1977). These tanks were mainly constructed to store and regulate the erratic monsoon rainfall which are heavy during certain periods. The primary purpose

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1/ There are a number of exceptions to this rule where tanks of more than 100 acres are not maintained by the PWD.

is to provide water for irrigation, with secondary purposes of providing water for livestock and fish production. Ludden, while studying the patronage and irrigation in Tamil Nadu, observed that rich peasants dug wells, chiefs built tanks and kings built large dams (Ludden, 1979). Mostly the tanks were constructed under the Zamindari system and such tanks remained under the control of chiefs until the Zamindari system was abolished.[2/] Further, he also observed that tank construction in the past played a key role in the ritual-based system of entitlement to control land resources. Through the construction of a tank the local chief generated resources for gifts to temples.

> "It was this system within which irrigation facilities were constructed, maintained and regulated by the same organization units which controlled cultivation processes as a whole--that confronted British administrators in the nineteenth century. The British were highly impressed by the extent of tank irrigation they found." (Von Oppen and Subba Rao, 1980)

After the British conquest of the Tamil country in 1800, the continued importance of eminent native personalities in financing irrigation was overshadowed by the growth of government as a centralized patron and planner. The British saw irrigation only as a means to obtaining land

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2/ In the sixteenth century the Muslim kings began to introduce new structures, at the same time recognizing the agrarian system and the land revenue system. Accordingly, the tax was collected by the Zamindar, who represented the power at the village level. He was a kind of sovereign's vassal, or simply a peasant who was a little more important than others. Originally, the Zamindar was not a landowner, but with the collapse of the Mogul Empire his powers and responsibilities, hence his influence increased. Subsequently, the British, during the early days of their rule in India, found it difficult to deal directly with the cultivators for the collection of land revenue. Hence, the British, in applying their judicial concepts, made the Zamindars not only a collector of taxes but also a land-owner with all the attendent rights. Slowly, the Zamindars became the authorities in the villages thus enforcing their power and rules.

revenue and, in general, the state sponsored projects had to run a profit (Ludden, 1979). The financial test of irrigation schemes were used as the test of their utility (Palanisami, 1980).

Development of tank irrigation after independence has been very limited. The abolition of ownership rights in private tanks and the take over of Zamins by the government discouraged private investment in tank construction. In addition no agency was vested with the specific responsibility for operation and maintenance of the Ex-zamin tanks. Meanwhile, the availability of diesel and electricity operated pumps made groundwater development an easy means of providing irrigation. Further, the increased cost of operation and maintenance and the problems connected with raising the water charges made it difficult for the irrigation department to expand tank irrigation.

Even then, steps were taken to improve the condition of the tanks. With the advent of "Grow More Food Campaign" in Tamil Nadu, separate divisions were formed during 1949-50 for tank repair and improvement. At the time of take over of the Zamins the need for tank renovation was recognized by the government and repairs were made to a number of tanks. The regular Food Production Division was given responsibility for renovating tanks based on the specification given by the Tank Restoration Scheme (TRS).

Tank Restoration Scheme

The state was divided into a number of river basins, each of which was divided into minor basins for the purpose of investigation by the Tank Restoration Scheme (TRS) started in 1961.[3/] First a detailed investigation of the

3/ As early as 1883, the government initiated the Tank Restoration Scheme and by Independence most tanks had been surveyed and many had been brought up to operational standards set by inspection parties under the scheme. District collectors themselves began the "circle system" of periodic tank inspection and repair in 1936. But it was scrapped in re-trenchment moves in 1942. See more details in David Ludden, "Patronage and Irrigation in Tamil Nadu: A Longterm View." *op. cit.*, p. 362.

tanks is conducted to determine what needs to be done so that the tank can irrigate the full registered ayacut or command area without undue foreshore submersion. Based on the standards fixed by the TRS, memoirs are prepared for official use for each tank. A local irrigation grant is made available to the panchayat unions to enable them to maintain the standardized tanks. The grant is released every year based on the annual needs. A program for maintenance with respect to all tanks in each panchayat union is drawn up with a five year repair cycle. Funds are provided based on the cost of repairs during a given year under the five-year cycle. In the case of non-standardized tanks under panchayat union control, a lump sum minor irrigation grant is allotted by the government for the use of local panchayat unions.

Operation and Maintenance

The government has the responsibility for developing water resources but little control over water distribution. The present system of water distribution is vested with the local village people, sometimes village committees. The PWD does the major maintenance works on tanks under its control such as repairing tank bunds, the tank sluices and breaches above the main canal outlet. Maintenance works below the canal outlet is primarily the responsibility of the farmers and the Panchayat Union. However, for some of the larger tanks the PWD does maintain the main canals. In the case of tanks with less than 100 acres, the local panchayat does the maintenance works, with financing from the minor irrigation grant (for non-standardized tanks) and from the local irrigation grant (for standardized tanks).

Normally the water is released from the tank by a waterman (called Madayan Thotti) who is paid by the villagers in kind after the crop harvest. Their appointment is hereditary but the waterman can be replaced if his service is not adequate. Their appointment is made by local committees in the villages.

The watermen also have responsibility for water use at farm level but their main job is to open and close the tank sluices as directed by the farmers. The regulation of water use is vested with the local people. The water distribution among the farmers is unequal resulting in losses in water productivity. However, reliable statistics are not available concerning the volume of water in the tanks and quantity used for irrigation. The usual assumption, which has continued over the decades or centuries, is that six acres of paddy (rice) can be irrigated during one crop season with one mil. $ft.^3$ of water. This figure is very low since more acreage can be irrigated with one mil. $ft.^3$ particularly on heavier soils. Paddy is the primary crop grown. It consumes a large quantity of water and the field to field irrigation results in heavy water losses. Water is normally drawn continuously from the sluices even when there is no apparent demand for water.

After the abolition of the Zamindari system, operation and maintenance of most of these tanks ceased to be under private control. Since then the amount spent by the PWD for tank maintenance has been insufficient. The land revenue and water charges go into the general fund and the amount collected has no relationship to the amount alloted for maintenance. The normal amount alloted by the PWD for the maintenance is Rs. 10-20 per acre while the cost of maintenance is Rs. 20-40 per acre. The revenue collected is also very low compared to the cost of maintenance. Normally water charges are based on the type of land (wet or dry within the tank command area) and fertility of land, which are determined arbitrarily by the village revenue official (Karnam). The water charges are also varied by land area and type of crop. The charge is about Rs. 6 to 10 per acre for rice depending on soil type and Rs. 1 to 2 for irrigated dry crops such as cholam, ragi cumbu, etc. There are also local taxes assessed by the Revenue Department in the form of local cesses and surcharges which usually amount to 3 to 4 times the water charge for rice. In the past, Zamindars collected about 40-50 percent of the produce from tank irrigated areas and spent much of the collection on operation and maintenance. Von Oppen and Rao argue that when the same person was responsible for maintenance and revenue collection there was a more direct reaction to urgently need repairs than is possible in the present system. The current system involves two separate departments acting separately on revenue collection and maintenance (Von Oppen and Subba Rao, 1980).

The Kudimaramathu (cooperative repair work) where each farmer provides labor for maintenance of minor irrigation works, which worked well in the past, is no longer effective. One of the reasons for this is that the benefits of maintenance are not proportional to the labor contributed. In addition frequent conflicts among the people concerning the sharing of tank water, results in non-cooperation in tank maintenance.

An additional problem that is directly connected with the operation and maintenance of the tanks is encroachment. There are foreshore lands which are normally classified as tank "Neer Pidippu Lands." Neer Pidippu Lands mean land that will be submerged when the tank is full (see Figure 2). But this land is cultivated when the water recedes in the tank. No claim can be made by the cultivators of such lands for crop damage due to submersion. The government rule is that if there is standing water for 21 days or more in the foreshore area of the tank, then the farmer should not cultivate this area. But the farmers have gradually raised the level of these lands by moving earth from the higher areas so that they are now mostly above water level.

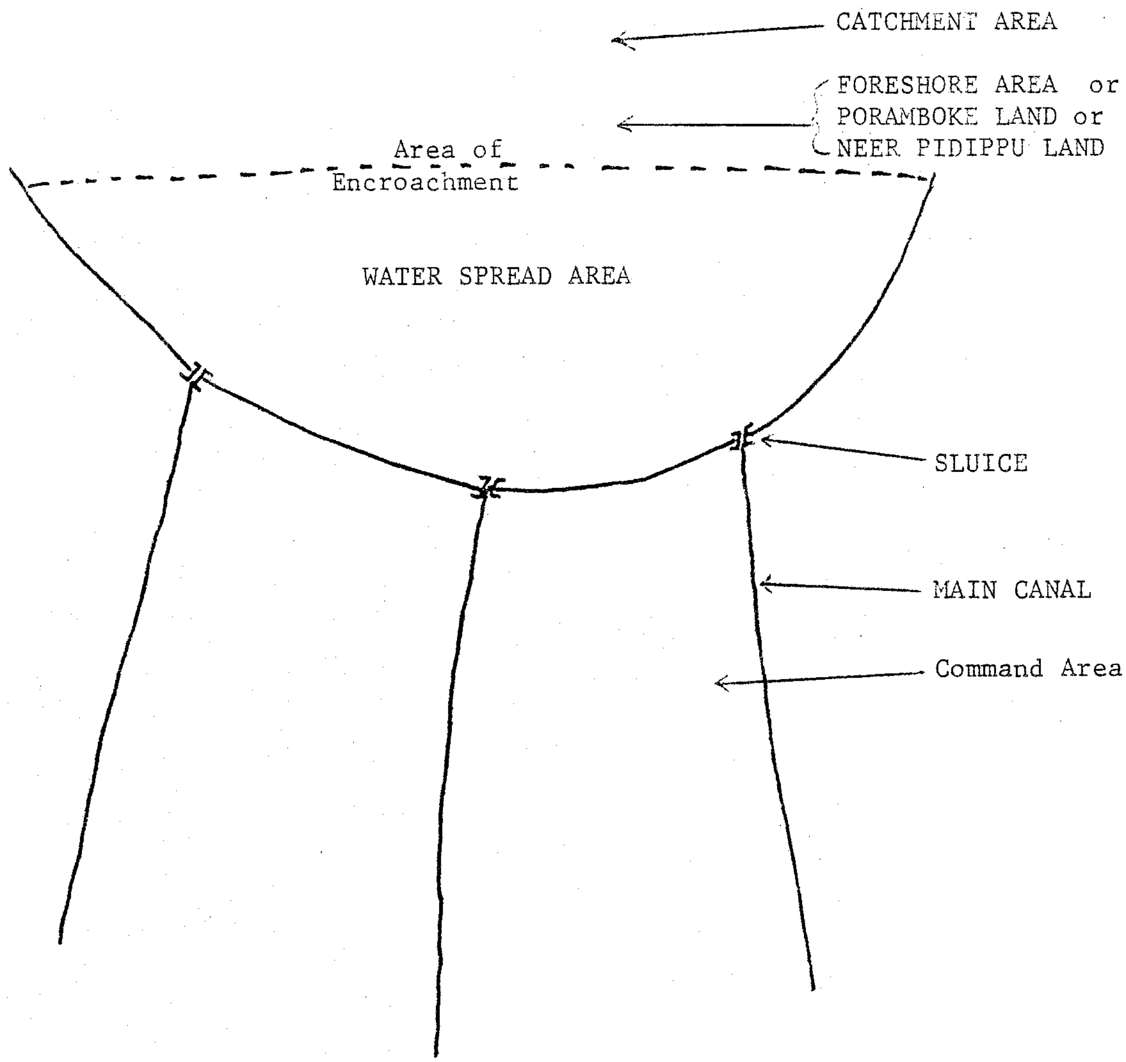

Figure 2: Tank Irrigation from Catchment to Command Area

After crops are grown for one or more years the cultivators can establish their rights (Department of Agricultural Engineering, 1982). The cultivators petitioned the government requesting that they be allotted the foreshore lands. The government after receiving a number of petitions from cultivators, gave orders to issue patta (right) to the cultivating farmers.[4/] This right is called Kulamkorvai Patta under which the foreshore lands legally became cultivated lands. The pattas were issued during 1971 (Government of Tamil Nadu, 1971). This caused serious problems for tank management, since it provided a strong incentive for cultivators to breach the levee and open sluices at night to prevent flooding of their crops in the foreshore areas. Thus, the storage capacity of the tank was reduced and the entire command could not be irrigated. After establishing rights, the encroachers also dug open wells to irrigate their crops, thus, making the foreshore areas irrigated lands.

Another potential water management problem is the farm forestry program launched by the State Forestry Department. Under this scheme, forest plantation of fuel wood species are raised in the water spread area under the control of panchayats. The scheme was introduced in 1963-64. It provides that the plantations should be raised and maintained by the Forest Department, for a few years and then given to the panchayats for future maintenance and harvesting at 50 percent of the market value. Currently, this program has been initiated by the Government of Tamil Nadu with funds from the Swedish International Development Authority. The *Acacia arabica* variety is being grown on a 10 year rotation. There is a difference of opinion between the PWD

4/ The speed of their orders and the penalty depends on the influence of the various farmers.

and the cultivators concerning tree plantations in the water spread areas. Many farmers feel that the tree plantations prevented them from taking silt from the tank to their lands. They are also afraid that the tree will consume a large quantity of tank water and that tree leaves falling in the water may be toxic. The PWD hopes that the tree plantations will help stop further encroachment and reduce soil erosion and siltation.

The fish production has not been important in most tanks due to their erratic water levels. However, in big system tanks the auctioning of fish is done by the Revenue Department. When only 40 days of irrigation water remains in the tank the fish auction is conducted. Normally the panchayat will be in charge of the fish auction. Many times where there is a formal or informal organization of farmers, the auction will be attended by a person representing the farmers' organization and the farmers will not allow outsiders to compete in the auction. This reduces competition and keeps the auction price low. After buying the right to the fish at a low price the farmers organization will reauction the rights to outsiders for a higher price and use the difference for tank improvement.

Conflicts do arise between the farmers and the owner of the rights to the fish. The owner of the fish wants to increase the fish catch. Consequently they will try to reduce the water level in the tank if it is high by opening the sluice gates and draining the water at night. In cases, where the water level in the tank is low they will attempt to keep water in the tank, to allow the fish to grow for a few more weeks by slightly closing the sluice gates at nights.

In tanks where there is inadequate water supplies, fish production is low and cultivators from the tank are allowed to fish freely at certain times. These times are announced in advance by the village headman. In general, for most tanks, auctions are not held regularly due to low fish populations. However, fish production is a potential means for increasing future tank benefits.

CHAPTER III

REVIEW OF PROBLEMS IN TANK IRRIGATION

The mere geographical concentration of irrigation tanks may be a necessary condition, but not a sufficient condition for effective utilization of the monsoon runoff for irrigating crops. In fact tank irrigation in most parts of the State is decreasing in area and in reliability. Water is unevenly distributed and supplies are unpredictable. In most of the tanks, the full command area is not being irrigated. What are the reasons for this declining performance of the tanks in providing assured water supplies for irrigation?

Some of the identifiable weaknesses of the tank irrigation systems are: silting of the tank beds, weak main levees, poorly functioning sluices, inadequate surplus weirs, poorly designed and maintained distribution systems, inadequate field channels, and seepage and drainage problems. In 1978 the PWD, of Government of Tamil Nadu, identified many of these defects and indicated that modernization of tanks should be given high priority. According to Ludden, 1979, the major tanks improvement in the past have included removing of silt from tank beds and reclaiming land encroached on by farmers and remodelling the channel systems connecting tanks.

Von Oppen and Rao, 1980, indicated that the PWD did not allocate sufficient funds for tank repairs and showed that the maintenance rates amounted to only about one-third of 1 percent of the capital value. Jayabalan, 1982, identified the major deficiencies in tank irrigation in Tamil Nadu as: inadequate maintenance of tanks and appurtenant works, technically deficient sluices and surplus weirs, siltation of supply channels, tank beds and irrigation water courses, seepage losses in the delivery system, poor water management, field to field irrigation and uncontrolled discharges from the tanks.

Palanisami, 1981, found that sluices which were located to suit past conditions, no longer met cropping requirements. Silting of sluices and damage to sluices have resulted in uncontrolled and continuous withdrawal of water even when there is no apparent need.

The Evaluation and Applied Research Department, Government of Tamil Nadu, 1979, in its evaluation of the tank irrigation suggested that the existing channels should be realigned to provide a more equitable distribution of water. The study also indicated that due to the absence of field channels, the farmers located near the supply channels derived maximum benefit while the lands farthest from the canals received very little water.

Wijayaratna, 1982, while studying the Gal Oya tank project in Sri Lanka observed that the uneven distribution of irrigation water resulted in the destruction of embankments, measuring devices, and control structures by water users. It also caused water use conflicts and a reduction in the use of allied farm inputs. Due to the deterioration of the physical system and lack of farmer participation in maintenance, substantial differences in water availability existed between head and tail locations.

Sakthivadivel, et.al., 1982, observed that water use efficiency in South Indian tanks has declined to as low as 25 to 35 percent in many cases. The reasons for the low water use efficiency were inadequate maintenance, lack of control over water releases and excessive use of water at the farm level. These inadequacies resulted in a permanent gap between the registered command area and the area actually irrigated by the tank. In their case study of Padianallur tank, they found that the lower fields received water only after the needs of the upper fields had been met. During times of low tank water supplies, the fields situated adjacent to the main channels took water directly through the openings made in the canal banks.

The Department of Agricultural Engineering, Government of Tamil Nadu, 1982, found that after Ex-zamin tanks were taken over by the Government, no agency was vested with the specific responsibility for their maintenance. As a result, the tanks lost their structural specification and much of their storage capacity due to silting. The water spread near the foreshore also offered a tempting terrain for encroachment. Encroachers prevent submersion of their crops by not allowing full use of the tank storage capacity. They open sluices at night or breach the levees to drain the tanks. In many tanks, the foreshore encroachments are so severe that these tanks no longer provide storage but only function as a channel to feed water into the sluices. Water in such tanks does not last for the entire cropping period and the crops frequently fail. The department also indicated that due to the lack of water release arrangements, water withdrawal is continuous which results in drainage problems in the lower areas. In another Tamil Nadu study, flooding of the adjoining areas was reported due to inadequate capacity of channels to dispose of the surplus water from the tank. The channel and tank capacities had been reduced due to encroachment and lack of maintenance (Elumalai, 1982).

Easter, 1982, in a report on tank irrigation in Northeastern Thailand indicated that land ownership patterns and legal status, ability of farmers to organize, cost of construction and production potential were important factors in determining the success of tank irrigation. He hypothesized that a small variation in farm size would foster better farmer cooperation in the distribution of water. Where the variance is high, the influence of large farmers will tend to be high and they will dominate water use decisions. Further, he observed that urban and farm encroachment is a serious problem in many old tanks in India. It is encouraged by the uncertain legal status of the water spread area and substantially reduces the tank storage capacity.

A cross cultural analysis of tank irrigation made by Doherty, 1982, revealed that for localized irrigation systems participation is more important than authoritarianism. He quoted different cases where tanks were built by colonizing group of households and water rights were shared along with land rights. He indicated that cultivation of the tank bed itself, although practiced in the past under certain circumstances had later been forbidden on government tanks such as Pul Eliya in Sri Lanka. This was done because the possibility of cultivation tempted individuals to breach the dam in order to hasten the time when planting could start in the tank bed.

Sivanappan, 1982, found that many tanks are badly silted, the sluices and bunds are not maintained and there are no arrangements to remove surplus water. These failures are more common in non-system tanks than in system tanks. When water is available in the tank, farmers plant paddy and this has not changed over the years even though high siltation rates have reduced tank capacities. He indicated that water losses in the unlined and improperly maintained irrigation channels are 25 to 30 percent. Seepage from these channels causes flooding of adjacent fields which reduces crop yields. Elumalai, 1982, while studying the farmers views on modernization of tanks in Tamil Nadu, indicated similar problems in tank irrigation.

In Karnataka, Sundar and Rao, 1982, reported that the tanks sluice gates are operated by the Soudi, an employee of the Irrigation Department. He follows the instructions of the maistry (work inspector) and the irrigation engineers. In tanks where the Soudi is absent, farmers themselves operate the sluices. Below these main outlets, it is the responsibility of the farmers to distribute the water among themselves. Although the maintenance of the field channels is the responsibility of the farmers, they perceive it as the responsibility of the Irrigation Department and generally do not maintain the channels. The study concluded that the farmers feel that the most important prerequisite for an effective water users organization is a good physical system and the appointment of Soudi to solve water use conflicts.

In Arputharaj's study of tank irrigation in Tamil Nadu, 1982, he found that the farmers refused to maintain the tanks. As a result the channels are in very bad condition. In non-system tanks it takes 7 to 10 hours for water to reach the last field, with heavy seepage losses. The water shortages are very severe at the end of the canal. The author reported unauthorized cultivation in the head reaches resulted in water scarcity for the tail end farmers. In the system tanks, flooding and seepage problems occurred in the head portions while drainage and silt accumulation problems plagued the tail enders. No overall water scarcity was found in the system tanks. The main problem was uneven water distribution due to the lack of an adequate Laskar (waterman) to allocate the water. The author recommended that separate studies be conducted to identify the specific probems of tank irrigation in different locations.

Adul Apinantara, 1981, studied the cooperation and conflict among water users in Northeastern Thailand tank irrigation. He found that water theft was the most important factor which caused water shortages followed by blocking of the canals, violation of rules and excess water use. There were no water fees and no restriction on the amount of water used, resulting in excess water use and conflicts among farmers. The majority of the farmers in the Water User's Association (WUA) participated regularly in cleaning and repairing the irrigation channels and wanted punishment and sanctions for non-participants.

The AID project paper on small scale irrigation (tank irrigation) in Northeast Thailand, 1980, indicated that failure of the tank systems was probably the result of indequate system operation and maintenance practices, lack of commodity markets, and insufficient technical assistance. Recommended improvements included the rehabilitation of the embankments, repair and extension of the lining on the main and lateral canals, construction of turnouts, provision of drainage facilities, more bridges crossings, completion of on-farm distribution systems, provision of lateral surface roads and construction of a service center building at each tank.

Chambers, 1979, also found in South India that the physical position of fields relative to channel is critical. Farms near the top of channels have an immense advantage in terms of access to water. In the absence of countervailing custom, social sanction or physical force, the top enders satisfy their own needs before allowing water to flow down the channel to the farms below. Further he found that the Karai system and any other system of time rationing is liable to deliver less water to tail enders because of seepage and evaporation losses en route. However, in certain villages, priority was given to tail enders first. In some cases they varied the rotation of water among farmers. Farmers at the head-end were the first to obtain irrigation in the first rotation. The second time water was delivered to the tail-enders first. In one village, where tail-enders had been suffering from water shortage a partial solution was to discourage those with pump-sets from using tank water. In the Sri Lanka the head-end farmers used excess water and thus substituted water for labor in weeding, without considering the plight of tail-enders.

Elumalai, 1982, indicated that the cropping pattern in the tank systems normally consists of rice in the first season followed by a second crop only in the head reaches. The second crop is subject to water availability in the tank and wells. The availability of wells in the command area acted as disincentives for farmers to cooperate in maintaining the system. The most critical and highly sensitive issues were the conflicts between different villages which benefited from the same tank and the conflicts between different political, communal or social groups within a village. The problems identified by the government agenices included, the inability of State irrigation engineers to control water releases or enforce water management practices, inadequate farmer maintenance of the supply channel, water stealing, and field to field irrigation.

Finally, Rajagopalan and Palanisami, 1981, identified the following constraints in tank irrigation: poor organization and management of the tanks, seasonal shifts in the distribution of rainfall, the lack of data on water inflows, outflows, and losses, and inadequate data on the size of catchment and command areas.

Summary

The analysis of tank irrigation particularly in India has not been an important research topic until very recently. In fact, it has been one of the most neglected aspect of irrigation in much of Asia. Studies have considered state tube wells, private tube wells, and large scale reservoir projects. However, few researchers have thought that tanks were important enough to study.

Current studies seem to indicate that the researchers were not the only ones to neglect tanks. The problems found plaguing tank irrigation suggest that governments in general have neglected tanks. In fact, the government of India took over responsibility for private tanks (Ex-zamin) and then failed to meet any of that responsibility. Therefore, tanks in India, as well as in Thailand and Sri Lanka, are faced with a wide and complex set of problems. Most of the problems are related to three aspects of tank irrigation: maintenance, water distribution, and encroachment. In large irrigation systems these issues would be dealt with directly by the government. However, this may not be feasible for most tanks because of their small scale and the high cost of providing government services to each tank. This means that the whole question of farmer cooperation and the farmer's role in tank irrigation is one of the keys to the whole problem. If farmers can organize to maintain the tank system and distribute the water evenly among farmers, then tank irrigation is very effective. When farmers do not organize, encroachment occurs, the tank silts up and water is wasted even when many farmers are short of water.

There are also problems that cannot be effectively dealt with even by farmers working together. This involves major damage to irrigation canals and the main dam structure. In addition, farmers are not familiar with important aspects of irrigation technology that are needed to increase farm production and income. Finally there tends to be a great deal of uncertainty about how much tank water will be available. Therefore the government should consider providing at least four inputs into tank irrigations: (1) structural investments in selected tanks, (2) assistance to help farmers organize, (3) technical assistance to improve the farmers irrigation techniques and (4) improve information for villages on weather conditions, particularly rainfall.

CHAPTER IV

IRRIGATION IN THE RAMANATHAPURAM DISTRICT*

The ancient history of Ramanathapuram is bound up with the history of the prosperous Pandyan dynasty which ruled the kingdom comprising Madurai, Ramanathapuram and Tirunelveli regions from 1st century A.D. until the early part of the 16th century. In 1063 A.D. it was conquered by Rajendra Chola but the Cholas ruled only for a short period. After the Cholas, rule passed into the hands of Mohamedans who goverened it for the Emperor at Delhi until 1365 when the Pandyas regained control. Aided by the kings of Vijayanagar who were at the zenith of their power, Parakrama Pandya Deva started a new line. The kings of Vijayanagar exercised the supreme authority over the Pandyas but did not interfere in their administration. Although the history of Ramanathapuram district prior to 1600 A.D. is involved in obscurity, there is enough evidence to indicate that the Pandyan dynasty has had a long historical influence on the district.

It seems probable that Muthukrishnappa when he became Governor of Madurai in 1609 A.D. re-established Sadeika Tevan Udieyan as a 'Sethupathy' on the throne of Ramanathapuram to protect the pilgrims traveling to the holy shrine at Rameswaram. That is why he came to be known as Sethupathiy or the guardian of the Isthmus of Rameswaram. Frequent disputes over the succession resulted in internal feuds. However, the regimes of Sethupathy Kuttan, Reghunatha Sethupathy and Kilavan Sethupathy were noted for their achievements and prosperity. It is after the death of Kilavan Sethupathy in 1710 that the

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*The history is drawn from Ramanathapuram District Gazetter, Government of Tamil Nadu, Madras, 1972.

Ramanathapuram region became divided. In 1730, Seshavarna Thevan, a popular chieftain of Ramanathapuram, along with the King of Tanjore and Kattya Thevan deposed Bhavani Shankara, the Sethupathy, and distributed the lands among themselves. Seshavarna Thevan became the Raja of the country, "of the fertile lands on the banks of Vaigai" and the 'harbour of Tondi". He assumed the title of Raja Mutha Vijaya Raghunatha Periya Udeiya Theyan and was subsequently known as Raja of Sivaganga. During this period the Nayaks regime in Madurai became weak and the last of the Nayaks died in 1731.

After the fall of the Nayaks the country fell into the hands of Chanda Sahib. In 1741 Chanda Sahib was forced to cede his ill-gotten dominion to the Mahrattas who were in turn driven out in 1744. Mohamed Ali and Chanda Sahib were then the rival claimants for the throne of Carnatic to which the districts Tirunelveli, Ramanathapuram and Madurai then belonged. The cause of Mohamed Ali was espoused by the English while Chanda Sahib had the Support of the French. This gave rise to a series of conflicts in the Carnatic. Upon the downfall of the Nayaks in the 1731, the local chieftains; i.e., the Poligars or Palyiakarars, began to assert their independence. The more powerful among them were the Sethupathy of Ramanathapuram and the Raja of Sivaganga who were the chiefs among the Poligars. The recent history of Ramanathapuram district is largely the history of these two chiefs.

The English who came to support the cause of the Nawabs finally annexed the country. The East India Company were persistently at war with the Poligars. To suppress the revolting Poligars the English fought several wars--one in

1755 in which Colonel Heron led the army and another in 1783 by General Joseph Smith when Ramnad country was subdued. In addition Fullarton led another expedition when the Marudu brothers were replaced by the Rani of Sivaganga. The final attempt in 1801 was by Colonel Agnew who fought the Marudu brothers at Kaleiyarkovil. Before the end of the year the rebellion had been completely stamped out and the country was quiet. By this time the Nawabs were quite powerless and had handed over the management of the country to the English by 1781. Following the fall of Srirangapattinam in 1799, the English assumed entire control of Government after making a monetary provision for the Nawab family. This was done under the Treaty of 1801. Although the Ramnad country was ceded to the British Government in 1792 the British Collector did not take charge of the administration until 1795. In 1799 Mr. Lushington was appointed Collector and, based on his report, the Paliyams of Ramanathapuram and Sivaganga were made permanently settled Zamindaris under the provisions of the 1802 Regulation. The two Paliyams continued as Zamindaris till the Zamindari system was finally abolished in 1948.

The present district of Ramanathapuram came into existence on June 1910. It was carved out of portions of Madurai and Tirunelveli districts. The taluks of Srivilliputtur and Sattur formed part of the old Tirunelveli district. The seven taluks of Aruppukottai, Sivaganga, Tirupattur, Tiruvadanai, Ramanathapuram, Mudukulathur and Paramakudi were formerly organized into the two Zamindaris of Ramanadathapuram and Sivaganga. The two Zamindaris covered an area of 3,708 sq. miles out of the total area of 4,828 sq. miles in Ramanthapuram District.

Climate and Rainfall

The climate is hot and dry in Ramanathapuram except in the coastal area where the heat is mitigated some what by the sea. The maximum temperature is rarely above 94° Fahrenheit and minimum seldom below 68°F. April to June are the hottest months. The temperature during these months is generally at its peak. The mean daily temperature is generally not below 70°F and the lowest temperature is often recorded during December or January. By the close of February the temperature starts to rise. The rainfall is low and often capricious. The normal annual rainfall is 820 millimeters. It is less than the State annual rainfall of 950 mm. The district rainfall records show that Tirunelveli has the lowest followed closely by Ramanathapuram. In addition there is wide rainfall variation among taluks in Ramanathapuram District (see Appendix I for details of the rainfall variation over time).

The seasonal average rainfall indicates that the maximum concentration of the rain is during October-December followed by June-September (see Table 7). The rainfall during the winter and hot weather periods is very low. The coefficient of variation for the different seasons based on the last 47 years indicates that the variation was highest during winter period, followed by Southwest monsoon. The rainfall during Northeast monsoon period is the most important for filling the tanks.

Irrigation

Tanks form the chief source of irrigation. Seasonal rivers and small hill streams provide some irrigation while wells serve as a supplemental water source particularly in tank irrigated areas. The total gross area of irrigated crops was 662,750 acres and irrigation tanks accounted for about 80 percent of the area and wells 19 percent.

Table 7. Rainfall and Rainfall Variation During the Four Seasons

Season	Period	Normal Rainfall (mm)	Average Rainy Days	Coefficient of Variation (C.V.)
				percentage
Southwest monsoon	June-Sept	186.1	12	51.27
Northeast monsoon	Oct-Dec	448.8	22	38.50
Winter period	Jan-Feb	56.6	5	91.45
Hot weather period	March-May	124.9	5	49.34
TOTAL		816.4	44	24.76

Source: Rainfall records of Ramanathapuram District and Director of Statistics, Government of Tamil Nadu, Madras, 1935-36 to 1980-81.

Tanks

Ramanathapuram district may be aptly described as "the land of tanks". Of the over ten thousand tanks in this district, 13 percent are under Panchayat unions control, 15 percent under the control of Public Works Department and 72 percent are nonstandardized or Ex-zamin tanks. The Ex-zamin tanks are not maintained properly and there is tremendous scope for increasing the irrigation potential, through rehabilitation or modernization programs. The topography of the district is well suited for the construction of tanks. These tanks are fed partly from their independent catchment and partly from the diversion of water from rivers and jungle streams through canals. A special feature of the tanks in the district is their construction in series. The surplus water escaping over the weir of one tank feeds the lower tanks. There are some series of over 20 tanks. These tanks have both advantages and disadvantages. One advantage with the system is that the return flow after irrigation which might otherwise be wasted finds its way into a lower tank. The main disadvantage is that the whole system can be damaged during heavy rains. The irrigation works deteriorate and eventually some are completely abandoned.

Rivers and Streams

The only major river is the Vaigai. It rises in the Western Ghats and enters Ramanathapuram after flowing through Madurai. It enters Sivaganga taluk and flows in a south-easterly direction across Sivaganga, Paramakudi and Ramanathapuram taluks and empties into the Ramanathapuram tank, with the surplus flowing to the sea near Uchipuli. The Arjunanadi, Vaipar, Mudangiar, Virayanadi, Mannarkottainadi, Gundar, Kanal Odai, Manimuthar and Thenar are all minor streams. Their water flow is highly uncertain and is fully utilized in filling tanks.

Canals

A number of canals extend from rivers such as the Vaigai, Manimuthar, Gundar, etc. and feed tanks along their course. But no control exists at the head of these canals. During rainy season, farmers prepare cross bunds or Korambu, as they call them, in the stream to divert water into the channels. This practice of irrigation has been used for a very long time. There are 93 channels issuing from the Vaigai river in Ramanathapuram district of which 53 are on the right side and 40 on the left side feeding 108 and 103 tanks respectively. These channels serve an aggregate of 105,200 acres in Sivaganga, Paramakudi, Mudukulathur, Ramanathapuram and Tiruvadanai taluks.

Wells

Wells supplement tank water sources throughout the district. There are about 66,208 wells in the district, accounting for about 5 percent of the wells in the state. Normally the wells are dug wells located in the tank command areas and used to supplement tank water.

Drought Prone Area Program (DPAP)

Ramanathapuram district is one of the two districts in the state selected under the Drought Prone Area Program and all the developmental works are executed under this program. The major program is the community well scheme. The scheme is now shared equally between state and central governments. Previously this scheme was under the Panchayat unions' control. Since 1980 it has been under the control of the Agricultural Engineering Department of the Government of Tamil Nadu. The groundwater potentially available in the district is estimated at 0.39 million acre feet. Funding was cleared in December 1980 for 26,338 new wells under the DPAP. The goal is to develop and utilize wells at the rate of 1000 open wells or bore wells per year. The wells are to be concentrated in the tank command areas. After the completion of each well, it is given to the Panchayat Union for operation and maintenance. The main objective of the scheme is to provide water for raising nurseries before the rainy season and to raise a second crop of millet after the tank water is exhausted.

Soil Conditions

The western taluks of Sattur, Srivilliputtur and Aruppukottai are mainly covered by black loamy soil which is suitable for growing cotton, chillies and millet. The calcareous nodules (Kankar) found in this soft clay loam soil is probably due to the limestone bands occurring among the Archaean bed rocks. It is believed that the black color is due to a rich humus content rather than its lime content. Large portions of Tirupattur and Sivaganga taluks, especially where the sedimentary rocks are present, are covered by a hard red laterite. This hard laterite is a poor soil and hence large tracts are left as thorny jungle unfit for cultivation. The percentage distribution of soils in the major taluks of the district is shown in Table 8.

Table 8: Soil Distributions in Ramanathapuram District

	Irrigated				Non-irrigated			
Taluk	Black loam	Black sand	Red loam	Red sand	Black loam	Black sand	Red loam	Red sand
				- percentages -				
Srivilliputtur	7.0	...	2.0	...	63.0	1.0	24.0	3.0
Sattur	2.2	0.4	...	...	81.4	1.2	1.4	13.4
Aruppukottai	18.9	3.4	...	1.8	55.3	1.0	3.7	14.5
Paramakudi	...	34.5	...	...	...	65.5	...	...
Triuvadanai	...	24.0	...	...	...	76.0	...	...
Mudukulathur	...	...	...	...	37.4	...	...	62.6
Sivaganga	...	...	37.8	...	...	...	62.2	...
Ramanathapuram	9.0	...	18.0	...	43.5	...	1.0	28.5

Land Utilization Pattern

Of the total geographical area of 3,122,155 acres, 38 percent was the net area sown, current fallow was 27 percent, other fallow was 7 percent and forests accounted for 3.8 percent. The high percentage of current fallow was mainly due to the uncertain irrigation water supply and the erratic rainfall. The corresponding figures for Tamil Nadu state are: net area sown 46 percent, current fallow 11 percent, other fallow 4 percent and forests 15 percent (see Table 9).

Table 9. Land Utilization Pattern in Ramanathapuram District and Tamil Nadu State

Land Use	Ramanathapuram District		Tamil Nadu State
	Area (acres)	Percent	Percent
Total geographical area	3,122,155	100.0	100.0
Forests	119,578	3.8	15.4
Barren and uncultivable land	49,912	1.6	4.8
Land put to non-agricultural uses	574,060	18.4	12.6
Cultivable waste	102,080	3.3	2.9
Permanent pasture and other grazing lands	8,340	0.3	1.4
Land under miscellaneous tree crops and groves	17,580	0.6	1.5
Current fallow	839,902	26.9	10.9
Other fallow lands	220,245	7.0	4.2
Net area sown	1,190,458	38.1	46.3

Source: Director of Statistics, Season and Crop Reports of Tamil Nadu, Madras: Government of Tamil Nadu, 1976-77, 1977-78.

Cropping Pattern

The cropping in the district consists mainly of food crops. Paddy is the main crop with millets grown in the non-irrigated dry areas. Of the total area sown, about 37 percent was under paddy. Cumbu, Cholam, Ragi (millets) crops constituted about 8, 2, and 5 percent respectively of the sown area. Food crops including cereals and pulses account for 74 percent of sown area. Among the non-food crops, cotton accounted for 11 percent of the sown area, followed by groundnut crop with 6.5 percent. When compared to the state, this district provided 9 percent of the net area sown and about 22 percent of the state's cotton area (see Table 10). Eight percent of the states' paddy

Table 10. Area Under Major Crops in Ramanathapuram District and Tamil Nadu State

Crop	Area (acres)		Percent
	Ramanathapuram District (1)	Tamil Nadu State (2)	(1 ÷ 2)
Paddy	444,247	5,527,914	8.0
Cumbu	98,210	920,097	10.7
Cholam	25,248	1,668,275	1.5
Ragi	70,568	698,640	10.1
Total Cereals	734,751	9,730,827	7.5
Total Food Grains	774,871	10,877,401	7.2
Total Food Crops	876,895	12,228,394	7.1
Cotton	134,892	615,948	21.9
Groundnut	77,637	2,440,807	3.2
Net area sown	1,190,458	13,717,012	8.7

Source: Director of Statistics, Season and Crop Reports of Tamil Nadu, Madras: Government of Tamil Nadu, 1975-76.

and 11 percent of the cumbu were grown in the district.

Agricultural Labor

The total population of the district in the 1981 census was 3.3 million. The rural population was slightly under 2.4 million and the urban was slightly under a million. The growth rate in total population between 1971 and 1981 was 16.4 percent; rural 13.0 and urban 26.2 percent. The percentage of rural population to total population was 74 percent in 1971 and 72 percent in 1982. The occupational distribution of the population was 36 percent cultivators, 27 percent agricultural laborers and 37 percent other workers. The marginal farmers (less than 2.5 acres) and small farmers (between 2.5 and 5.0 acres) acount for 84 percent of the cultivators. The average size of the holding was 3.2 acres.

Summary

Ramanathapuram district is one of the largest and driest districts in Tamil Nadu. Irrigation is critical for high crop production and an absolute necessity for a second crop. The large area of fallow land, over one-third of the geographical area, and the low and highly variable rainfall all point to water as the constraint to increasing agricultural production and farm income.

Tank improvement appears to be a good option to easing this constraint. Ramanathoporam district has over ten thousand tanks most of which are in varying degrees of disrepair. Tanks account for 80 percent of the irrigated area in the district while wells cover another 19 percent. In addition the interaction between tanks, and groundwater recharge is quite important. Therefore, even well irrigation cannot be considered separately from tank water supplies.

CHAPTER V

CHARACTERISTICS OF THE TEN TANK SAMPLE

Ramanathapuram district was selected for the present study as indicated earlier, because of the large number and variety of tanks used for irrigation. Ten standardized tanks with varying dimensions were identified for the field research (see Table 11 and Figure 3). These dimensions include: dependability of water supply, size, investments in improvements and age of tanks. Before the tanks were selected discussions were held with the Public Works Department (PWD) engineers in charge of the tanks at various locations in the district,

Table 11. Sample of Ten Tanks with Command Area and Type

Numbers	Name	Command Area (acres)	Tank Type[a/]
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	System
10	Thuthai	93	Non-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. The details are given later.

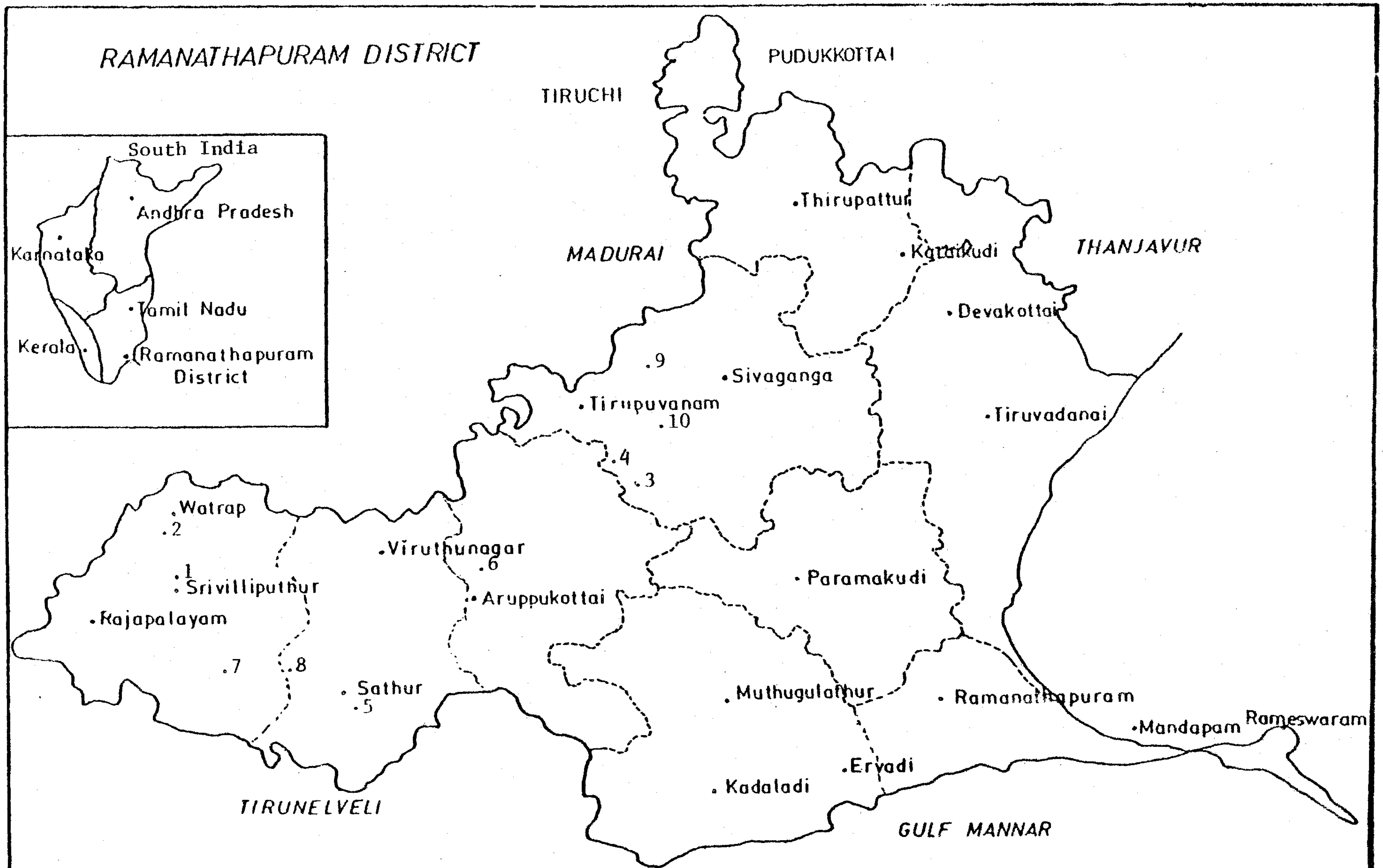

Fig.1 LOCATION OF SELECTED TANKS

NOTE: The numbers refer to the numbers given in Table 11 for the selected tanks.

the local Agricultural Officers, Revenue Department officials and farmers. Frequent visits were made to various tanks at different times before the final ten tanks were selected.

A simple random sample of two hundred farmers was selected from the ten tanks, with the help of the list of farmers maintained by the Revenue Inspectors. Data were collected by personal interview with the farmers. Frequent indepth discussions were also held with the PWD engineers, agricultural officers and Forestry Department officials, regarding the system operation and maintenance, crop cultivation and tree planting in the catchment and waterspread areas. At the farm level, information was collected on land tenure, area planted and harvested, cropping pattern, tank water (timing and quantity), ground water (quantity and cost), input use, stress effects, field location, asset position, credit supply, farmer organization, channel maintenance, encroachment, and fishery benefits. Yield information was obtained from farmers after the harvesting and threshing had been completed. Frequent group discussions were held with the farmers to determine their overall opinion of the tank irrigation system such as new tank construction, lining of the channels in existing tanks and installation of community wells.

The data were collected for the crop season, November-December 1981 to February-March 1982, because tank water is available for irrigation for only this one season in many of the tanks. In some of the system tanks two crops are possible. However, only two of the ten tanks can depend on getting enough irrigation water for two crops in a year.

Scale and Type of Tanks [1/]

The tanks selected for the study are standardized tanks, where the Tank Restoration Scheme has fixed standards for further operation and maintenance. Among the 10 tanks, five tanks are system tanks, and five are non-system tanks. Responsibility for maintenance of eight tanks with command areas exceeding 100 acres is vested with Public Works Department (Irrigation Department) and for the two tanks with command areas below 100 acres, it is vested with local Panchayat Union (Revenue Department) (see Table 11). The annual water storage of the tanks is equal to capacity of the tanks times the number of fillings. Hence, as the number of fillings increases, the area irrigated increases. The "effective" command area is determined by these two factors. The water stored per acre of command area reflects approximately the water supply available in the tank to irrigate one acre.[2/] Normally, however, these measurements are not correct, due to silting and encroachment which has reduced the tank capacity.

The system and non-system classification of tanks is a broad concept initiated when the tanks were constructed which is not relevant for many situations today. For example, Tank 7 and 8, although they are under the Watap System (Pilavakal Dam) and are classified as system tanks in a series of

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1/ Scale or size of tanks generally refers to the total capital investment in the tanks and the size of the command area. Type of tanks refers mainly to source of water supply for the tanks, degree of water adequacy, water allocation procedures, organization and management of the tanks, and other infrastructural facilities available.

2/ The water stored per acre = $\frac{\text{capacity of the tank x number of fillings}}{\text{total command area}}$

The figures are presented mainly to give a rough idea of the water available in the different tanks.

connected tanks, they do not receive water from the Pilavakal Dam. This is because the upper tanks in the system irrigate two crops of rice and use all the water before it can reach the lower tanks. In the case of Tank 9, which it is part of the Vaigai system, it often receives adequate supplies, but these supplies are only obtained when farmers spend considerable time and effort to illegally divert water from Vaigai channel.

An alternative classification of tanks is to divide the tanks on the basis of a regular availability of a perennial source of water. Under this classification the Watrap Big Tank (Tank 2) and Piramanur Tank (Tank 3) are classified as Dependent tanks, since they have a perennial source for regular tank fillings. The other eight tanks are Independent tanks, since they are independent of any perennial sources. These Independent tanks depend on rainfall, small unpredictable jungle streams during rainy periods and in a few cases diversions, illegally, from canals serving other tanks.

The mean length of the main canal is about 1.65 kilometers and it ranges from 0.8 kilometers in Tank 10 to 2.32 kilometers in Tank 4 (See Table 12). The length of the main canal is related to the tank size, and affects the time required for water to reach the tail and the potential for water losses. In the Dependent tanks, the length of the main canals may not be a serious problem but in the Independent tanks, the length is very important in the distribution of the available water supply.

The supply channels are the channels which branch off from the main canal. These channels are maintained by the farmers while the main canals are maintained by the Irrigation Department (PWD) or the Panchayat Union. In the Dependent tanks, there is no difference between the main canal and supply channel in terms of water availability. But in the Independent tanks,

Table 12. Description of the Ten Sample Tanks, 1982.

Description	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8	Tank 9	Tank 10
Villages Benefited	3	1	3	6	2	1	1	1	1	1
Full Tank Level (feet)	451	553	NA	490	180	55	445	495	NA	NA
Length of Bund (feet)	10,920	7,080	6,800	22,000	5,700	4,500	12,780	4,200	NA	NA
Area of Water Spread (mil.ft.^{2})	9.10	14.30	14.60	35.50	2.80	4.31	15.60	2.48	NA	NA
Capacity of Tank (mil.ft.^{3})	50.00	81.00	89.45	113.50	12.47	20.08	85.00	5.60	12.10	6.98
Number of Fillings	3.0	2.0	3.0	1.5	2.0	1.5	2.0	3.0	1.0	2.0
Total Annual Storage (mil.ft.^{3})	150.00	162.00	268.35	170.25	24.94	31.20	170.00	16.80	11.80	13.96
Water Stored per Acre (mil.ft.^{3})	0.15	0.18	0.17	0.14	0.13	0.13	0.43[a/]	0.13	0.13	0.15
Number of Sluices	4	4	7	6	3	2	3	3	2	1
Mean Length of Main Canals (km.)	2.03	1.42	1.21	2.32	1.27	1.40	1.71	1.59	1.10	0.80
Mean Length of Supply Channels (km.)	0.84	0.26	0.30	0.71	0.21	0.32	0.42	0.31	0.45	0.38

NA = not available

a/ This figure is too high and is probably around .13 because both the capacity and number of fillings are over-estimated.

during periods of inadequate water supply, water is rotated among the supply channels along the main canal. Hence, water distribution problems will be greater when the main canal is long and there are a large number of supply channels (see Figure 4). For the longer supply channels, the farmers have to wait for their individual turns to irrigation, and there is heavy seepage losses during transit. When there are a large number of supply channels along the main canal, the time interval between rotations will be long, resulting in conflicts between farmers. When there is no rotation, chances for conflicts are even greater as each farmer will try to divert water from the supply channel, resulting in little or no water for farmers at the end.

Characteristics of the Farms

The average number of farms per tank varies from 49 in Tank 10, to 1,086 in Tank 4. The number of farms is slightly lower in Dependent tanks, compared to Independent tanks. The average number of fragments is 1.97 per farm and it ranged from 1.3 to 2.5 fragments. Generally, if the number of fragments is high, the problems of water distribution to all the fragments will also be high. During times of inadequate tank storage, farmers tend to leave fragments fartherest from the tank fallow. The average size of land ownership is 1.80 acres, which is much less than the district average of 3.20 acres. The average size of total land or operation unit in the tank command areas is 2.01 acres.[3/] Farm size is slightly larger in the Dependent tanks.

The instability of water supply in the Independent tanks has had two important impacts. First, a significant number of farmers in the Independent tanks have had to sell part of their lands to stay in operation during

3/ Total land = owned land + leased in land - leased out land.

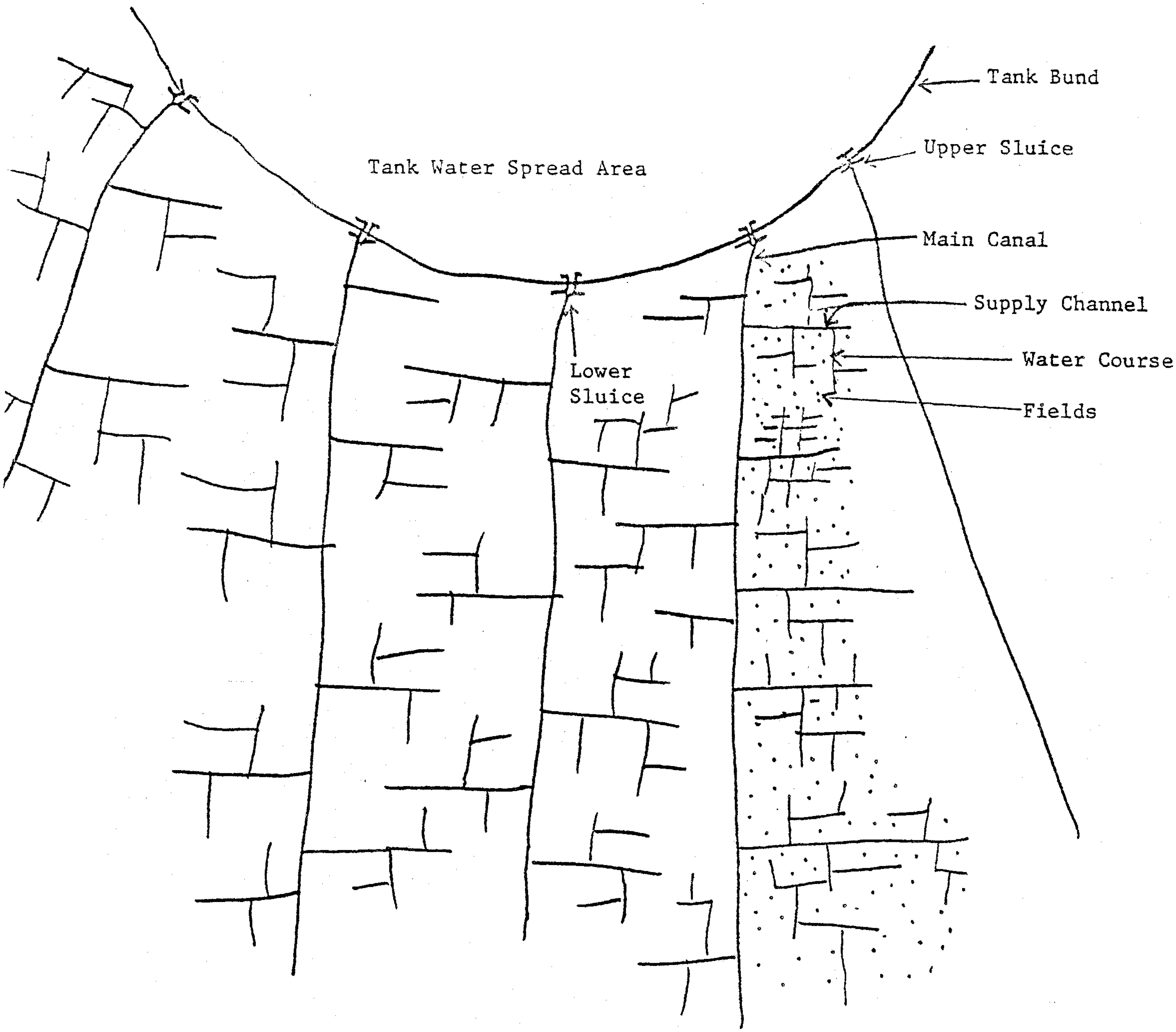

Figure 4. Location of the Main Canal, Supply Channel and Water Courses

drought periods while this is very uncommon for farmers served by the Dependent tanks. Second, land values are much higher in the Dependent tanks. Differences in land values range from Rs 3,100 to 10,290 per acre (see Table 13). Since the value of water is capitalized into land values, this difference in land values is mostly due to differences in water supplies available over time. Thus the two Dependent tanks plus tank number 10 must have the most dependable water supply while tanks 5 and 6 have the worst supply relative to the command area.

The presence of wells is also an indication of inadequate tank water. It is common to supplement tank water with well water, when the tank supply is exhausted. In most of the tanks, all of the wells (open wells) are owned by private individuals except in Tank 4 and 9 where there are also community wells.

The major crop is paddy, followed by sugarcane and banana. The sugarcane and banana are grown mostly in the Dependent tanks and by a few farmers who own wells in the Independent tanks. The difference between the total land area and paddy area is due to sugarcane and banana production in the Dependent tanks and the fallow land in the Independent tanks. Rather than have a total crop failure, many farmers in the Independent tanks will use the limited irrigation water on only part of their land leaving the rest fallow.

Water Supply and Distribution

The water supply to the two Dependent tanks, is from Pilavakal Dam and Vaigai Channel, along with the seasonal monsoon rainfall during July-September and October-December. For Independent tanks, the major source is rainfall. Hence, during periods of monsoon failure, the Independent tanks have inadequate water. In half or more of the past 10 years, seven of the Independent tanks did not receive even enough water to adequately irrigate one crop. During the same 10 years farmers served by the Dependent tanks had only two years when water was

Table 13. General Characteristics of the Sample Farms by Tank, 1982.

Items	All Tanks (Average)	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8	Tank 9	Tank 10
Total no. of farms	357	642	461	738	1086	96	127	198	81	88	49
No. of fragments per farm	1.97	2.25	2.50	1.85	2.15	1.65	2.10	1.30	1.55	2.05	2.30
Leased in-land (acres)	.28	.51	.52	.36	.18	.05	.37	0.15	0.17	.08	.31
Leased out-land (acres)	.07	.18	--	.12	.02	.03	.05	0.21	--	.02	--
Owned land (acres)	1.80	1.67	2.57	2.21	1.16	1.96	1.69	1.96	1.77	1.05	1.96
Total land (acres)	2.01	2.01	3.09	2.45	1.32	1.98	2.01	1.90	1.94	1.11	2.27
Land Value (Rs/ac.)	13,656	12,995	19,190	18,400	11,950	8,900	9,525	12,925	12,950	11,425	15,300
Wells [a] (No./every 10 acres)	1.5	3.5	1.0	1.0	3.0	0.1	0.1	3.5	3.0	0.5	0.8
Paddy area (acres)	1.52	1.55	2.57	2.05	1.12	1.13	1.15	1.29	1.60	0.95	1.81

a/ Tanks 2, 3, 5 and 6 have wells which are not used in a year with a normal rainfall.

not adequate to irrigate two crops. In those two years the water supply was adequate to irrigate one crop (see Table 14). Farmers try to predict the failure of the monsoon and to divert at least some water into the tank to provide some irrigation and to recharge the wells.[4/] The tank water also is the main source for washing clothes and cleaning and watering the cattle.

Farmers at most of the tanks had strategies to obtain additional water supplies when the rainfall was not favorable. In the case of the two Dependent tanks and Independent Tank 10, the additional supply is drawn from the perennial sources, based on their water rights. Tank 9 used unauthorized diversion channels to divert water from a Vaigai branch channel which was carrying water to other tanks. This has led to a court case against the villagers. In the case of Tanks 7 and 8, farmers' have 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. Based on this, 37 tanks were considered as a system of tanks under the Pilavakal Dam. But due to lack of a separate channel, to carry water from the Pilavakal Dam to each tank in the series, water had to flow from tank to tank. This resulted in the over use of water in the upper tanks 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.

4/ Farmers expect rains during the June-July and October-November months and if there is no rain or insufficient rain then they try to adjust to the situation. Sometimes there may be rain but the tank does not get an adequate supply, as the runoff above the catchment is diverted to adjacent tanks by other farmers.

Table 14. Tank Water Supply During Last 10 Years, 1972-82.

	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8	Tank 9	Tank 10
					number					
Total Years	10	10	10	10	5 a/	6 a/	10	10	10	10
					number					
Years of Inadequate Supply d/	6	2	2	6	3 c/	3 c/	6	7	5	3 b/
					percent					
	60	20	20	60	60	50	60	70	50	30

a/ These tanks were constructed recently and opened for irrigation 5 and 6 years ago.

b/ This tank receives water from Vaigai River, but can't get a full supply due to problems in diverting the water from the Vaigai. Farmers are not cooperating in maintaining the canals for diverting the water.

c/ The number of years with inadequate supply in these tanks represents the water inadequacy for the entire tank command area. The actual area that can be irrigated by these tanks is only about 57 and 21 percent of the command area for Tanks 5 and 6 respectively. Even in one year the water supply was inadequate to irrigate the smaller area. If the area that currently can be irrigated in these two tanks is considered as the command area then 80 percent of the years these tanks have had adequate water for irrigation.

d/ The supply is inadequate when there is not enough tank water to irrigate one crop of rice in the command area.

Consequently they demanded more water from the Dam. These efforts have been partially successful for Tanks 7 and 8.

In the case of Tank 4, additional supplies were made available through the installation of two community wells operated by the Panchayat unions. In Tank 9, work to install a community well was in process during the survey. 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), when the tank supply is exhausted. The other strategy, combined with the above, is to maintain strict rotation schedules so that farmers receive water every 4 to 6 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 user's organization at the tank level and the cooperation of an organization of private well owners.

No strategies had been developed by farmers at the two new tanks, 5 and 6, to supplement inadequate supplies. Since these tanks have been in use for only five and six years, the time and experience are probably not sufficient for the farmers to develop strategies to obtain additional water supplies for the tank[5/] (see Table 15).

5/In addition, the total command area could not be irrigated due to the manner in which the tank was constructed. Farmers in the higher level command area do not receive water while farmers in the lower command area obtain full irrigation. This might be one of the reasons why no efforts have been made to obtain additional supplies. The detailed problems are discussed later.

Table 15. 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]	
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.

Water Supply and Management [6/]

Substantial opportunities exist for water management to provide additional water. The strategies adopted at each tank reflect the importance of additional water supplies. Six out of the 10 tanks experienced water scarcity and depended heavily on the groundwater in the latter part of crop season. For the two new tanks the water supply is adequate to irrigate farmers in the lower lands but not adequate to irrigate the total command area. In the case of Tanks 2 and 3 which had abundant or adequate water, there is no need for additional water in most years. For tanks with water scarcity, farmers managed to obtain additional supplies by diverting water from small streams or rivers and by pumping groundwater. Through farmer cooperation farmers increased the number of irrigations by increasing the total water supply and improving the water allocation at the field level. This was made possible through a more centralized decision making process, compared to the tanks with abundant or adequate water, where decision making was decentralized. At the tank level, water supply as a whole increased and at the field level the number of irrigations increased. This is an indication of how farmers can substitute management for water during scarcity periods.

The benefits of substituting management for water are comparatively high (see Table 16). Tanks 1, 4 and 9 had high per acre water management expenditures and net returns per acre. In the case of tank 10, the value of additional water was high since their management efforts along with their rights to Vaigai channel water were enough to completely fill the tank. For tanks 7 and 8, the

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6/ Management refers to the ability of farmers to bring additional water supplies to their tanks and organize to improve water allocation.

Table 16. 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	78	0.4	-	-	-
6	High	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	8	200	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 hence 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.

expenditure was not adequate to obtain sufficient water supplies. In addition the supplies were allocated inefficiently due to poor cooperation among farmers.

Normally, inadequate supply will result in better water distribution among farmers.[7/] However, the water distribution varied among tanks. In the case of Dependent tanks (Tanks 2 and 3) the water was adequate and distribution was satisfactory. In the case of Tanks 5, 6, and 10, the water supply was adequate 50 to 70 percent of the time but distribution was poor. In the case of Tank 10 farmers did not cooperate in the water distribution due to a long standing conflict between two different groups in the village. Some of the influential farmers had encroached on the tank bed area and always tried to drain the water from the tank to avoid submersion of their crops. Sometimes the farmers did not even cooperative in the diversion of water from Vaigai river to fill the tank.

The water supply was inadequate while the distribution was satisfactory in Tanks 1, 4, and 9. In each of these tanks farmer organizations were operating very effectively. In Tank 1, the association of well owners was cooperating with the other farmers to distribute the tank and well water.[8/] In Tank 4, the operation of the two community wells and an informal farmer's organization facilitated the water distribution. In Tank 9, the farmers are receiving government support in constructing a community well due to their cooperative efforts.

7/ For details on inadequate water supply and efficient distribution methods see K. Palanisami, "Pattern of Water Allocation, Use and Management in Lower Bhavani Project, Coimbatore District, Tamil Nadu", unpubished Ph.D. Dissertation, Tamil Nadu Agricultural University, Coimbatore, India, 1980.

8/ Sometimes, if tank water is very scarce, the well owners will not use the tank water. The rotation of the tank water will then be between non-well owning farmers. This is done upon the request of the Irrigation Panchayat Committee (the farmers' organization for the tank).

For Tanks 7 and 8, the water supply was inadequate and the distribution was poor at the supply channel level. This is primarily due to the conflict between the different caste and political groups in the villages. The farmers with the larger holdings dug their own wells and would not cooperate in the distribution of tank water. At times, tank water was in such short supply that it was not sufficient for one rotation of 6 to 7 days to the entire command area. When the water scarcity was so acute that even the wells went dry, the farmers began to demand their rights to water from the Pilavakal Dam. The farmers were successful in getting some water from the Pilavakal Dam. However, it was not distributed efficiently since farmers did not cooperate in allocating the water among farmers except at the water course level.

One of the important factors influencing the water distribution was the heterogeneity of farmers. The greater the variance in farm size the greater were the problems in water distribution. In tanks where the variation in farm size was small, the water distribution was satisfactory (see Table 17). In Tanks 1, 4 and 9, the coefficient of variation by farm size was small (31, 24 and 33 percent respectively) compared to Tanks 5, 6, 7, 8 and 10 (86, 67, 72, 91 and 104 percent respectively). In Tanks 2 and 3, the farm size variation was comparatively high, but the distribution was satisfactory because of the abundant water supply.

The method of water distribution varied from continuous flow to rotations on a fixed time schedule, depending on the tank water adequacy. In many of the tank irrigated areas paddy cultivation started with a nursery on a small plot of land irrigated with groundwater before the release of the tank water. Tank

Table 17. Water Supply and Distribution Within Tanks, 1982.

	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8	Tank 9	Tank 10
Water Adequate and Distribution Satisfactory		X	X							
Water Adequate but Distribution Poor					X	X				X
Water Inadequate but Distribution Satisfactory	X			X					X	
Water Inadequate and Distribution Poor							X	X		
Coefficient of Variation in Farm Size (Percent)	31	66	51	24	86	67	72	91	33	104

water is used for nursery preparation if rainfall comes early or there are too few wells to meet the water demands. The seedlings are transplanted on the ploughed field after about 30 days in the nursery. Farmers generally apply more water during the field preparation and normally more water will be released from the tank up to transplanting.[9/] Usually tank water is adequate until transplanting. After transplanting, the water level in the tanks will be low, and if additional water supplies for the tanks are not available from rainfall or perennial sources, farmers have to depend on groundwater.

Water is generally allowed to flow continuously in the main canal from all the sluices until the tank water supply is exhausted. In the Dependent tanks, continuous withdrawal was also found at the supply channel and water course level since water in the tank was adequate (see Table 10).[10/] For Independent Tanks 5, 6, and 10, the main reasons for the continuous withdrawal at both supply channel and water course level were the lack of organization and conflicts among farmers. This resulted in a rapid exhaustion of the tank water

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9/ Land preparation will take from 10 to 20 days. This is, again, dependent upon the availability of bullock labor for ploughing and human labor for transplanting. In general, about 30 percent of the farmers own bullocks in the Independent tanks and about 65 percent in the Dependent tanks. Many well owners demand labor from farmers to whom they sell well water. It is hard for farmers to refuse such requests since they depend on well owing farmers for irrigation water and for raising a nursery.

10/ The water course is the link between the supply channel and farmers' fields. The maintenance of the water course is the responsibility of farmers. Each water course is owned by a few farmers compared to the supply channel which is owned by many farmers (see Figure 4 for details).

Table 18. Methods of Water Distribution by Tank, 1982.[a]

Water Distribution	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8	Tank 9	Tank 10
Sluices Outlets	C	C	C	C	C	C	C	C	C	C
Main Canals[b]	C	C	C	C	C	C	C	C	C	C
Supply Channels	R	C	C	R	C	C	C	C	R	C
Water Courses or Field Channels	R	C	C	R	C	C	R	R	R	C

Note: C = continuous flow
R = rotation method

a/ The sluice openings in tanks 1, 4, and 9 are done according to the instructions of the farmer leaders in the village. For the other tanks, any farmer can open or close the sluices according to his needs.

b/ Each main canal starts at an individual sluices. If water is allowed to flow continuously through the sluice, then there will be continuous flow in the main canal (see Figure 4 for explanation).

supply and low yields. Tanks 1, 4, and 9, followed rotation schedules both at the supply channel and at the water course levels. The existence of farmers' organizations was a major factor in establishing the rotation system for water distribution. In Tanks 7 and 8, continuous flow occurred at the supply channel level and a rotation was used at the water course level. A rotation was not used at the supply channel level due to the lack of cooperation discussed above. They also felt that the water supply might be exhausted before the rotation schedule was completed. Equity in water distribution is a major objective in these tanks. The operation of the community wells is also a good indication of farmers' willingness to cooperate in water distribution.[11/]

When the water is in short supply and farmers adopted rotation irrigation both at the supply channel and water course levels, there still is no guarantee that they will obtain enough water for the entire crop season. For example Tanks 1 and 4 had tank water for only 11 and 21 days repectively (see Table 19). The additional supplies had to come from wells. Tanks 7 and 8 had only 22 and 28 days of tank water which may have lasted longer with a supply channel rotation. For Tanks 9 and 10, additional supplies were obtained to fill the tanks although rotation schedules for Tank 9 allowed the farmers to produce a

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11/ The question why there is no community well in Tank 1 has different answers. Many farmers said that there is no good site for a community well in terms of high water yield. Other farmers reported that the powerful and influential well owners do not want community wells since the market for their well water might be affected. A detailed investigation of the sites for a well will soon be conducted by PWD. However, the PWD said that different farmers demanded wells in different locations since they all wanted easy access to well water for their fields.

Table 19. Starting and Closing Dates and Total Days of Irrigation from Tanks, 1982.

Tanks		Months					Total days of tank Irrigation[a/]
		November 1981	December 1981	January 1982	February 1982	March 1982	
Tank 1	S	27th	6th				11
	C		2th, 10th				
Tank 2	S	4th continuous supply for 6 months					
	C						
Tank 3	S	9th continuous supply for 6 months					
	C						
Tank 4	S	20th					
	C		10th				21
Tank 5	S	16th					
	C				20th		96
Tank 6	S	22th					
	C				18th		89
Tank 7	S	29th					
	C		20th				22
Tank 8	S	26th					
	C		23th				28
Tank 9	S		1th	25th			
	C			18th	11th		67
Tank 10	S	17th	17th	6th			
	C		10th, 30th	22th			55

S - Starting tank irrigation
C - Closing tank irrigation

a/ The days of irrigation refer to one crop season.

good rice crop.[12/] Although Tank 10 received two fillings from the Vaigai river, water was inadequate at the end of the crop season, because of poor water management. Tanks 2 and 3 had no water problem and Tanks 5 and 6 had adequate tank water because only part of the planned command area is irrigated.

The next important question is how do individual farmers adjust cropping practices to inadequate water supplies? This is important for Tanks 1, 4, 7, 8, 9 and 10. About 45 percent of the farmers irrigated with tank water until it was gone and then supplemented it with well water (Table 20). Another 28 percent of the farmers irrigated their crop until the tank supply was exhausted and then supplemented with well water and heavy fertilizer applications. When tank water was not continuously available, these farmers applied heavy applications of nitrogen fertilizer during every irrigation. They believe that the fertilizer will help overcome the crop damage caused by erratic and inadequate irrigation. A number of farmers also applied high rates of fertilizer when well water was limited by high demand and price.[13/] Again they seemed to try to compensate for the reduction in well water by applying more fertilizer.

12/ The Poovanthi tank is a Dependent tank with water from the Vaigai river and the farmers were generous enough to divert some water to Tank 9 after repeated request from the farmers of Tank 9. Tank 9 farmers already diverted water illegally from Vaigai that was supposed to go to other Dependent tanks in the region. Sometime, Tank 9 will also receive drainage water from the Madapuram Tank, which is a Dependent tank receiving water from the Vaigai River.

13/ Well owners by mutual understanding, increase the water charges when the demand for water increased. In such cases farmers had no other alternative but to pay high fees for well water.

Table 20. Farmer Adjustments to Inadequate Tank Water Supplies, 1982

Adjustments	Mean Yield (kg/acre)	Percentage of Farmers Adopting [a]
Irrigate only part of farm	1,016	4
Reduce the water applied per acre	695	7
Supplement with well water	1,321	45
Apply more fertilizer and supplement with well water	781	28
Increase the irrigation interval	650	5
No adjustment	NE	11

NE = Negligible, no irrigation after tank supply was gone.

[a] Total number of farmers was 120. The farmers in tanks 2, 3, 5, and 6 did not have to adopt any adjustment strategy since they had adequate water supplies for the area irrigated in their tanks.

Four percent of the farmers reduced the area under irrigation, although initially they planted their entire area with paddy thinking that the tank would fill. They had to reduce their area planted by from 30 to 50 percent.[14/] The farmers argued that if they did not concentrate the water on part of their land they would have had a complete crop failure. It is not possible for all farmers to irrigate their entire area by hiring well water because the pumping capacity is not large enough to irrigate the entire area.[15/] A few farmers (7 percent) irrigated all their crop land by reducing the amount applied per acre. Another group of farmers (5 percent) irrigated all their land with tank water and then supplemented with well water but used longer intervals between irrigations. These farmers irrigated once in 7-9 days instead of the regular interval of 4-5 days. The longer interval was used because of the high cost of well water (many well owners demanded advance payments before delivering the well water) and its limited availability. Eleven percent of the farmers abanded their fields once the tank water was exhausted. This was primarily due to the location of their fields relative to well water. Their fields were either a long distance from the wells or at a higher elevation. It was very difficult to deliver well water long

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14/ The cost of ploughing, planting, fertilizer, etc. on the land not irrigated after the tank water is exhausted is a dead weight loss to society.

15/ The well water was used only after the tank water was exhausted, as the well water has to flow in the same channels as the tank water. The well water could not completely supplement the tank water because of: (1) the slow recharge of the wells, (2) the high cost of lift at greater depths, (3) the pump capacity limited to 5 H.P.per pump, (4) the electricity available for only 6-10 hours per day due to general power cut by the State Electricity Board between March and June and (5) the frequent coil damage to the motors due to overuse and fluctuations in voltage.

distances through the supply channel and the water course since they are unlined and undulating, which result in high water losses.

The strategies adopted by the farmers resulted in a wide difference in paddy yields. The yield per acre was highest when the farmers were able to apply 2 acre inches of well water and irrigate at regular intervals of 4-5 days. Yields were cut in half when alternative strategies were used in attempts to irrigate the entire area planted. Yields were substantially higher if the area irrigated was reduced when the water supply was inadequate.

Costs of Paddy Cultivation

Under conditions of uncertain tank water supply and high priced well water, farmers tried to maximize their expected net return. Therefore, the costs and returns vary by type of tank and water availability. The average costs and returns are given in Table 21 for each tank. The average total variable costs was Rs 1200 per acre while the range was from Rs 1040 per acre in Tank 9 to Rs 1283 per acre in Tank 7. The average per acre yield of paddy was 1371 kg and the range was from 1,100 kg in Tank 7 to 1673 kg in Tank 2. The major cost, fertilizer, accounted for almost one third of the total cost in almost all tanks. Labor costs were the next big item with hired labor greater than family labor. The cost of tank water was low and fixed per acre.[16/] The cost of well water was over twice the cost of tank water in all areas irrigated by wells. The variation in cost of well water was due to differences in the quantities of

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16/ During periods of flood, drought or heavy pest and disease damage to the paddy crop, the Revenue Divisional Officer (RDO) may inspect the fields and can exempt them from 50 percent of the water charges.

Table 21. Costs and Returns from Paddy Cultivation by Tank, 1982

Items	Average for all tanks	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8	Tank 9	Tank 10
	-- rupees per acre --										
Cost of seeds and seedlings	70	67	61	53	66	90	82	81	74	66	61
Cost of fertilizer	420	409	386	386	416	408	399	548	444	417	389
Cost of plant protection chemicals	110	85	103	127	103	118	127	88	84	71	100
Cost of irrigation water:											
Tank water	35	34	36	34	30	45	46	30	30	30	31
Well water	83	106	a/	a/	60	a/	a/	82	113	61	75
Cost of bullocks labor	106	99	105	116	112	127	124	91	89	77	122
Cost of human labor:											
Family labor	126	114	85	111	126	101	118	155	146	203	96
Hired labor	250	266	352	329	193	284	310	207	195	116	248
Total cost	1,200	1,181	1,128	1,154	1,047	1,175	1,206	1,283	1,175	1,040	1,121
Yield of paddy (100 kgs)	13.71	13.87	16.73	14.56	11.02	15.87	14.89	11.08	11.66	14.46	12.65
Price per (100 kgs)	131	131	127	133	134	132	131	134	132	129	131
Total value	1,801	1,823	2,131	1,934	1,478	2,089	1,882	1,482	1,539	1,864	1,521
Value of by-product	112	122	116	121	112	102	110	100	101	100	117
Total return	1,913	1,944	2,248	2,055	1,589	2,191	1,992	1,581	1,640	1,964	1,637
Net return	713	764	1,120	901	668	1,017	786	298	466	924	516

a/ Do not use wells.

water used and the cost per hour.17/

The average net return per acre was Rs 713. It varies from Rs 298 in Tank 7 to Rs 1120 in Tank 2. The price of paddy is almost the same for all farmers. Hence the differences in net return is mostly due to differences in factor costs and yields. The high fertilizer cost in Tank 7 was one reason for the low net return. In contrast farmers in Tank 2 had one of the lowest average expenditures on fertilizer and the highest net return. For tanks with inadequate water the farmers appear to be applying too much fertilizer.18/

Tank Water Supply

The several factors that have influenced the tank water supply and benefits include: (1) encroachment by farmers in the water spread or foreshore areas of the tank, (2) the operation of water user organizations, (3) the type of tank (dependent or independent), (4) the sluice location (higher or lower elevations), (5) the condition of irrigation channel structures, and (6) commercial fish benefits (see Table 22).

17/ Farmers required four to six hours of pumping to obtain one irrigation of 2 inches depth per acre, depending on the distance between the well and their fields. The charge per hour of pumping from electric powered pumps varied from Rs 3.50 to 6.00 depending on the H.P. of motor and demand for water. The actual cost for one hour of pumping (electric) varied from Rs 0.80 to Rs 1.00. In the case of oil engines the pumping charge per hour varied from Rs 5 to 6 while the actual cost was Rs 1.80 to 2.00 per hour. In the case of electric powered community wells, the rate per hour varied from Rs 2.25 to Rs 2.50. This rate was based on electricity consumption, interest on investment and operator charges, assessed by the Revenue Department (Panchayat Union).

18/ The farmers applied fertilizer at an average rate of 54 :22 :22 kgs. per acre of N:P:K while the Agricultural Department recommended 40:20:20 kgs. of N:P:K for paddy. The cost per kg of fertilizer nutrients is N = Rs 4.92; P = Rs 4.60 and K = Rs 2.46. Farmers believed that more fertilizer resulted in higher crop yield. The Agricultural Department felt, based on the soil test in the tank irrigated areas, that farmers were over fertilizing.

Table 22. Tank Characteristics Affecting Water Management by Tank, 1982.

	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5	Tank 6	Tank 7	Tank 8	Tank 9	Tank 10
Encroachment	No	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Sluices[a/]	2 lower 2 upper	All lower	All lower	2 lower 4 upper	2 lower 1 upper	1 lower 1 upper	1 lower 2 upper	1 lower 2 upper	1 lower 1 upper	1 lower
Water Users' Organization	Yes	No	No	Yes	No	No	No	No	Yes	No
Tank type[b/]	Indept.	Depend.	Depend.	Indep.	Indep.	Indep.	Indep.	Indep.	Indep.	Indep.
Fishery benefit	Yes	Yes	Yes	No	No	No	No	No	No	No
Irrigation struc.[c/]	Sat.	Poor	Sat.	Sat.	Poor	Poor	Poor	Poor	Sat.	Poor

a/ Upper sluices refer to the sluices located at higher level in the tank which does not receive water when the tank level is low.
Lower sluices refer to the sluices located at lower level in the tank which receives water even when the tank level is low.

b/ Depend. - Dependent tanks, receives a regular water supply from perennial sources and have adequate water supplies throughout the crop season.
Independ. - Independent tanks, depend on rainfall for tank fillings and many times do not have adequate water supplies.

c/ Irrigation structures
Satisfactory (Sat.) = The structures are satisfactory if the tank sluice gates are present and lockable. Also the main canal and branch channels are maintained by removing the silts and weeds.
Poor = The structures are poor when the sluice gates are in a bad condition and cannot be locked. Also the main canal and branch cannels have an accumulation of silt and weeds.

Encroachment

Among the ten tanks, encroachment has occurred in six tanks. This means that farmers are growing crops where water is suppose to be stored (see Figure 5). As discussed in Chapter II, after encroaching for a few years, farmers applied to the government requesting that the lands be classified as permanently cultivated and that *patta* be issued.[19/] In most cases they claim that it was their original hereditary land.

To obtain *patta*, farmers do not allow tank water to stand for 21 days on their foreshore or water spread lands as they illegally drain the tank water at night. This results in conflicts between encroachers and farmers in the tank command area. The farmers in the foreshore start cultivation well in advance of the tank filling by using their own wells. The major crop is usually sugarcane. When the tank starts filling, the encroachers watch the water level and start draining the water from the tanks as soon as it appears that their crops might be flooded. This was the main reason farmers in several tank command areas suffered from inadequate tank water, although the tanks started out with sufficient water. This was further complicated by farmers who have lands both

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19/ If 21 days of standing water is observed on the land *patta* cannot be issued. The order is Kulamkorvai *Patta*, Board's Proceeding's (Perm) 212/May 13, 1971, Government of Tamil Nadu. *Patta* is the statement of permanency or right of land.

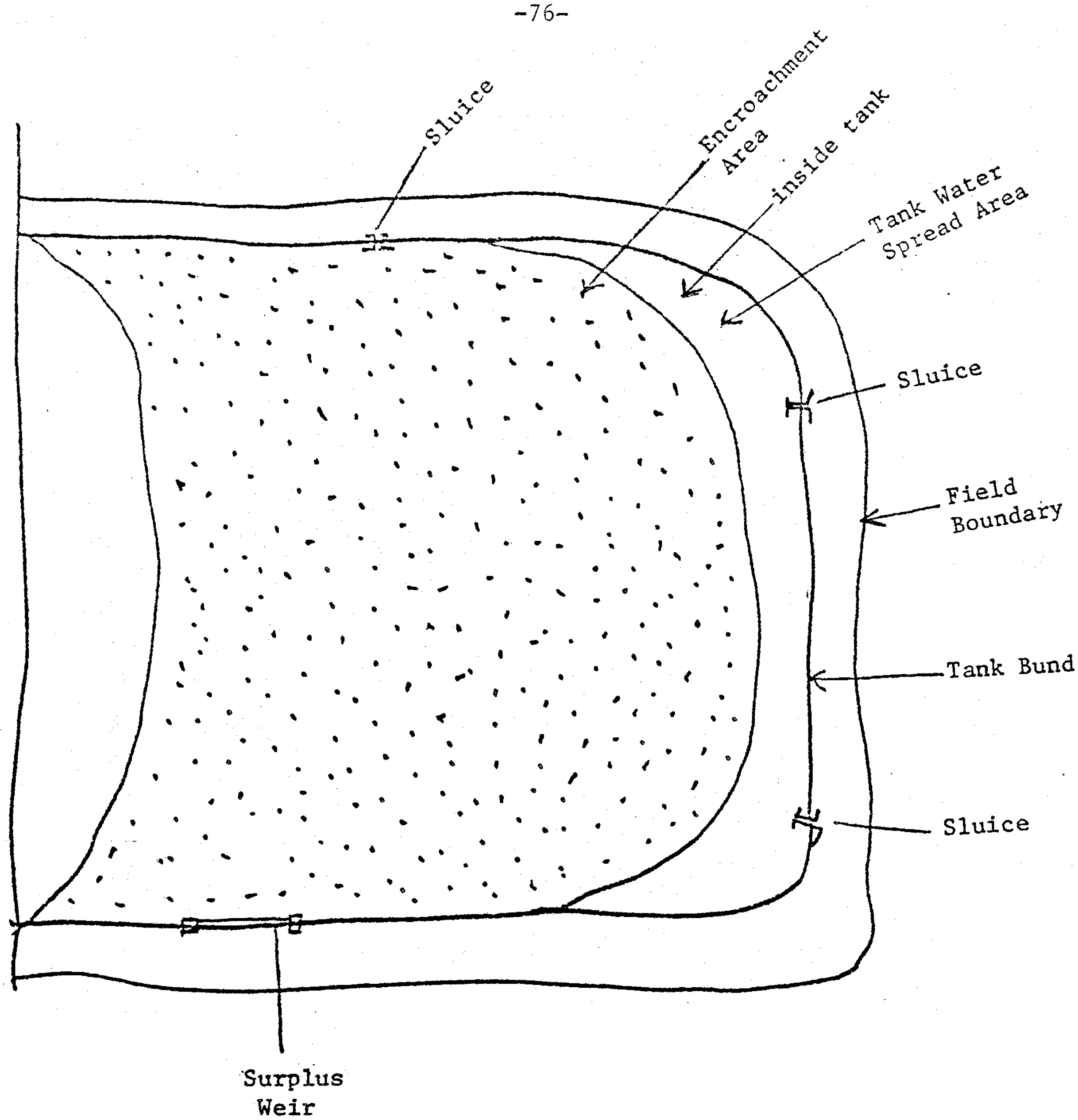

Figure 5. Tank with Severe Encroachment

in the foreshore and tank command areas. They are usually influencial farmers and have supplemental well water. Thus they discourage efforts of other farmers to organize at the tank level. Encroachment has a high payoff because yields are high on the foreshore area due to heavy silt deposits. The encroachers' pay a penalty, if patta has not been issued, equal to twice the regular water charges. After patta is issued, they pay the same water charges as farmers in the command area.[20/]

In terms of yield and input use the tanks without encroachment are performing better than tanks with encroachment (see Table 23). Yields are over 15 percent higher on the farmers served by tanks without encroachment. Another difference was in water source. Farmers faced with encroachment used much more well water and less tank water than those without encroachment.

Tank Type

Dependent tanks (2 and 3) have significantly higher yields than Independent tanks. The surface water supply in Dependent tanks was more than double the supply in Independent tanks. Well water was not needed in the Dependent tanks even for the second crop. Fertilizer use in the two types of tanks was about equal due mainly to the heavy fertilizer substitution for water in Independent tanks. The input and yield variability was low in the Dependent tanks as compared to Independent tanks.

Sluices

Location of the sluices is very important in determining the water supply at the farm level. The number of sluices in a tank depends on the size

20/ The penalty is very low compared to the benefits to encroachers and the loss to other tank farmers. Also, the exact verification of the encroached area and collection of penalty depends on the village Karnam's (revenue department official) discretion. Many times there is an underestimation of the encroached area due to pressure from the farmers.

Table 23. Yield and Input Use Under Different Tank Conditions, 1982

	Sluice		Encroachment		Water Users' Orgn.		Channel Structures		Tank Type		
	Upper (N=137)	Lower (N=63)	With (N=120)	Without (N=80)	With (N=60)	Without (N=140)	Satisfactory (N=57)	Poor (N=143)	Dependent (N=40)	Independent (N=120)	Average
Yield (kg/acre)	1,214	1,530	1,270	1,470	1,422	1,320	1,493	1,249	1,671	1,070	1,372
CV (%)	91	24	45	42	36	55	49	55	30	82	51
Casual Labor Use (mandays/acre)	29	41	38	40	41	35	45	31	48	28	38
CV (%)	66	42	68	63	65	71	55	76	47	70	48
Fertilizer Use (RS/acre)	413	426	438	401	414	425	398	440	386	452	420
CV (%)	63	44	33	34	24	52	46	52	31	60	69
Tank Water Use (inches/acre)	28	42	31	40	39	32	40	31	51	21	36
CV (%)	112	65	78	56	82	104	77	103	64	108	74
Well Water Use (inches/acre)	18	4	18	4	8	14	8	14	--	22	11
CV (%)	97	44	68	50	52	69	51	71	--	80	64

Note: CV = coefficient of variation.

of the command area, capacity of the tank and topography of the command area. There is no fixed rule to decide the number of sluices in a tank. As indicated earlier, most of the tanks were about 100 years old and originally the sluices were fixed according to the topography so that the entire command area could be irrigated. Due to poor maintenance of the tanks, silt accumulation prevents some higher sluices from providing their designed discharge. Sluices located at the lower levels are able to release more water for a longer period of time. Due to removal of silt near the bottom part of the tank, depressions usually occur around the lower sluices. The lower sluices can, therefore, release water from these depressions, even when the tank irrigation supply is almost gone.[21/] Thus a few farmers can irrigate two crops if they are located at the head position of a main canal coming from a lower sluice.[22/]

The difference in water flow was so high between upper and lower sluices, that normally the upper sluices draw one-third less water than the lower sluices. Consequently there is less demand for well water on farms served by the lower sluices. In four tanks several of the upper sluices were not even operating because the tanks were only 30 to 50 percent full due to low rainfall. Only in periods when the tanks are fairly full will the upper sluices draw water. Thus even when there is adequate water in the tank for the remaining crop season, areas served by the upper sluices may not receive water.

21/ It also is not uncommon for farmers using oil engines to pump the water out of the depressions. This water is sold to other farmers at the rate of Rs 6 to 7 per hour of pumping.

22/ Normally the dead storage (not available for irrigation) will form 10 percent of the total storage in the tanks. But due to depressions, the dead storage can form about 15-20 percent of the total storage in some tanks. This helps the farmers close to the lower sluices since they can pump water for their own crop or sell it to others.

In Tank 1, one upper sluice is not operating due to poor maintenance. In Tank 4, two upper sluices are not operating and many farmers have to depend on well water for irrigation. In Tanks 7 and 8, one upper sluice in each is not drawing any water for irrigation.

For the newly constructed tanks 5 and 6 the reasons for non-functioning of the upper sluices are different. In Tank 5, out of the total targeted command area of 187 acres only 108 acres (57.7 percent) were irrigated. In Tank 6, out of the total targeted command area of 234 acres only 48.3 acres (20.6 percent) were irrigated.[23/] The command area is at a higher elevation than upper sluices. Most of the farmers said that they were not consulted regarding the sluice location. In addition it was also reported that the tanks were constructed based on improper contour maps and a larger command area was included to raise the project returns.[24/]

The low and highly variable yields on the land served by the upper sluices relative to the lower sluices highlight the water supply problems (see table 23). Yields were 26 percent higher on farms served by lower sluices. In addition well water use was four and a half times higher on farms served by upper sluices. The coefficients of variation show that all input use was highly variable on farms served by upper sluices.

23/ Irrigation - Special Minor Irrigation Programme - Ramanathapuram district - Evaluation Report by the Board (F.P.). Ref: D 3/500 S/80, dated March 5, 1981.

24/ Based on contours the storage of the proposed tank is determined and the command area is fixed. The tank bunds are formed on the lower contours and that the command area is fixed. The sluices are fixed according to different elevations of the command area for easy flow of water from the tank. If the contours are not fixed properly then the location of the sluices will be wrong and will result in water distribution problems.

Water User Organizations

Another important aspect of water use is the organization of farmers to allocate tank water during periods of water scarcity. Water user organizations (WUO) are operating effectively in Tanks 1, 4 and 9. In Tanks 7 and 8 farmers are not organized at the main canal or tank level, but they are organized at watercourse level. In tanks where WUO exist, tank water scarcity is very common and the variation among farms in terms of land area and assets is very small. The yield and input use variation was greater for tanks without WUO while yields and tank water use were lower. This suggests that farmer cooperation has resulted in higher and more stable income and production.

In Tank 1, the Irrigation Panchayat Committee is functioning very successfully at the tank level. Well owners are organized, as are farmers at each supply channel and watercourse level to distribute the water and collect maintenance charges.[25/] Informal organizations are operating in Tanks 4 and 9 and their effects have resulted in the construction of community wells. Although water inadequacy was common in Tanks 7 and 8, farmers do not cooperate very well due to the conflicts between different groups of higher income farmers.

Channel Structures

The condition of the channel structures (main canal, supply channels and water courses) reflect the farmers efforts to use the tank water efficiently. In most of the tanks, farmers maintained the structures adjacent to their fields. All canals are well maintained in tanks

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25/ For more details see, V. Rajagopalan, 1982, "Changing Roles of Rural Institutions for Management of Tank Irrigaiton Systems", paper presented at the workshop on Modernization of Tank Irrigation: Problems and Issues, Centre for Water Resources, Madras.

1, 4 and 9, where WUO are operating effectively. For cleaning operations every farmer provides labor according to the requests of the WUO leaders. When farmers are unable to provide labor, they have to pay a penalty, equivalent to the current market wage of labor. This penalty is called Thitti and it is meant to discourage the farmers from going outside the area to work without providing labor for the common channel cleaning operations.

In other tanks the cleaning of the supply channels and watercourses is done by individuals or groups of farmers primarily for delivering well water. Well water is costly and farmers know that the flow is very low compared to tank water. Unless the channels and watercourses are cleaned the well water will not reach their fields. In tanks where the sale of well water was uncommon the channel maintenance was generally poor. As one would expect the yields per acre were 244 kgs. lower in tanks with poorly maintained channels (see Table 23).

Fish Production

Commercial fish benefits were important in only Tanks 1, 2, and 3. Due to inadequate water supply, fish production was not possible in most of the other tanks. A fish auction is held at Tank 1 when there is a 40 days supply of irrigation water. The rules governing the fish auction are fixed by the WUO. In Tank 2, due to its very dependable water source, a fish auction is held every year.[26/] The fish auction in Tank 3 is not as successful due

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26/ For Tank 1, the auction was conducted by the Revenue Department. Only one bidder was allowed by the tank villagers to bid at the auction and then only at a low price. The one bidder was from the WUO. The WUO reauctioned the fish to outsiders for a higher price with the difference used for tank improvement. In 1979-80 they received Rs 37,000 in the auction while in 1980-81 the price went up to Rs 52,000. Urgent repairs were made by the Farmers' Organization with this money and the money collected from farmers for tank maintenance. In the case of Tank 2, money from the fish auction is used to run local Elementary and High Schools. They sell their fish for between Rs 85,000 and 135,000. There is a committee to manage the fish auction which is separate from the school management.

to frequent exhaustion of the tank supply in between tank fillings. However, if farmers cooperate, benefits from a fish production could be increased.

CHAPTER VI

IMPACT ON PRODUCTION OF VARYING WATER CONDITIONS

Farmers, Irrigation Department and Revenue Department officials are aware of the seriousness of many of the problems facing tank irrigated areas. However, no one has quantified the impact of these problems on production and farm income. If the impacts can be estimated then the benefits from eliminating the problems can be measured. When these benefit figures are combined with the cost of alternative tank improvements, the highest return alternatives can be selected.

To measure the impact of water management problems on production two general types of models are used. One is the traditional Cobb-Douglas production function which includes dummy variables for many of the water management problems. The second model is a simultaneous equation model with five equations. It is hoped that this later model will separate the impact of the water variables between input use and yield. More water should mean higher yields and larger quantities of inputs applied.

Production Function Model

In the production model, rice yields are a function of a series of inputs including land, labor, fertilizer, management, water, etc. Observations from the 10 tanks are used to estimate the effect of inputs on farmer reported crop yields. Several different measures are used to represent selected inputs. For example, an attempt was made to account for both the quantity of water applied as well as the timeliness (quality) of the water delivered. A number of variables that influence yield are not included in the model such as rainfall, temperature, sunlight, soil type, and drainage. We feel that these variables were fairly constant across the sample. A general model was first developed on per farm basis and is described along with the variables in Appendix II.

Empirical Model

Modification had to be made in the general production model because of some fairly common statistical problems. For example, because of the high intercorrelation between land, fertilizer, total labor, and the cultural index, the model was changed from per farm to a per acre production function (see Table 24). In the final model the variable cultural index was excluded due to its unexpected sign and insignificance. Its exclusion left the results basically unaffected except that the size of asset coefficient dropped and became insignificant. Several other coefficients also declined slightly with the tank type dummy variable dropping in significance from 1 to 5 percent. Casual labor was used instead of total labor since it is a better measure of the marginal effect of labor on crop yield.

The Cobb-Douglas production function provided an extremely good fit to the data. This is not surprising since many other studies of Indian agriculture have found the Cobb-Douglas function provides the "best" fit to their data. The functional form is also less complicated when fitting a function with a large number of independent variables. The empirical model is as follows:

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

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

where Y = rice yield in kg. per acre after threshing

TW = tank water used in acre inches per acre

WW = well water used in acre inches per acre

Table 24. Correlation Matrix

	Rice Yield	Land	Ferti- lizer	Tank Water	Well Water	Total Labor	Casual Labor	Asset	Cultural Index	Tank Type	Sluice Location	Encroach- ment	Rehabili- tation	Water User's Organization
Land	0.40													
Fertilizer	0.31	0.95												
Tank Water	0.97	0.35	0.25											
Well Water	0.96	0.40	0.36	-0.38										
Total Labor	0.33	0.92	0.86	0.33	0.26									
Casual Labor	0.27	0.51	0.48	0.28	0.13	0.58								
Asset	0.18	0.57	0.26	0.15	0.14	0.52	0.27							
Cultural Index	0.44	0.87	-0.05	0.43	0.39	0.88	0.45	0.56						
Tank Type	0.23	0.15	-0.31	0.14	0.15	0.27	0.19	0.15	0.31					
Sluice Location	-0.60	-0.39	-0.04	-0.61	-0.50	-0.35	-0.36	-0.27	-0.37	-0.12				
Encroachment	-0.10	-0.02	0.41	-0.09	0.19	-0.05	-0.04	0.04	0.004	-0.16	0.03			
Rehabilitation	0.05	0.07	0.28	0.03	0.09	-0.01	0.12	0.04	0.12	-0.17	-0.22	0.29		
Water User's Organization	-0.20	0.11	0.62	0.15	0.25	0.16	0.07	0.07	-0.08	-0.10	-0.21	-0.09	0.27	
Channel Structures	0.05	0.12	-0.09	0.03	0.02	0.16	-0.07	0.12	0.14	0.26	-0.03	-0.01	0.06	0.03

CL = casual labor used in man days per acre

F = fertilizer used in rupees per acre

A = asset value or position 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 user organizations, 1 if organized
0 if no organization

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

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

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

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

Casual labor, CL, was obtained by converting all the hired children, female and male labor into man days based on the ratio of 3:2:1, which is the same ratio as their market wage rates. When more casual labor is used, yields should increase, $\frac{\partial Y}{\partial CL} > 0$.

The asset variable, A, includes the value of farm buildings, wells, irrigation structures and farm implements. A high asset position is likely to be related to greater influence in tank operation and management. In many cases, assets are directly related to well ownership. A high asset position should mean a high paddy yield, $\frac{\partial Y}{\partial A} > 0$.

The value of fertilizers, F, applied by farmers is a combination of Nitrogen, Phosphorus and Potassium. Farmers in the tank irrigated areas only grow short season HYV's which are well suited to tank irrigation where the water supply is usually limited to not more than three months. Within the relevant range of fertilizer applications, more fertilizer should increase paddy yields, $\frac{\partial Y}{\partial F} > 0$.

It was not possible to calculate the exact amount of water received by each farmer in each irrigation. Hence, the tank water, TW, applied by a farmer was estimated by multiplying the number of irrigations times the depth of irrigation and the total area under paddy. The irrigation depth was based on distance of the farm from the supply channel. If the farm is located between 0.0 to 0.3km from the supply channel, the depth is three acre inches. When it is 0.31 to 1.00km, the depth is two acre inches. Finally, if distance is 1.01km and above, the depth is one acre inch. The higher the amount of water delivered, the higher yield, $\frac{\partial Y}{\partial TW} > 0$.

The well water, WW, applied varies both by tank and farm. In some tanks farmers irrigate two to ten times with well water while in others no well water is used. To calculate the well water used by farmers, one irrigation is assumed to be two acre inches. Since well water is costly farmers limit their water applications to a depth of two inches. Most of the farmers used four to five hours of pumping which is sufficient for a depth of two inches per acre. The total well water used by each farmer was calculated by multiplying the number of irrigations from a well times two inches and the total paddy area irrigated. The greater the amount of well water used the higher would be the yield, $\frac{\partial Y}{\partial WW} > 0$.

The cultural index, CI, is based on the timeliness of farming operations and is used as a measure of management. The following crop cultural practices were included in the index: land preparation, planting, transplanting, fertilizing, weeding, irrigation, plant protection, and harvest operations. A score was allotted to each practice according to the timeliness of the farmer's performance of the operation as follows: timely application = 3, application with some delay = 2, and application with considerable delay or no application = 1. The scores for the individual activities were added to arrive at the cultural index for a farm. A higher managerial ability, as measured by a higher cultural index should result in higher yields, $\frac{\partial Y}{\partial CI} > 0$.

The tank sluice location, S, is classified as either upper or lower. The lower sluices deliver water over a longer period than the upper sluices, since the upper sluices are silted more heavily than lower sluices. To isolate this locational difference with respect to crop yield, a dummy variable is used to specify the sluice location. Farmers served by upper sluices should have lower yields, $\frac{\partial Y}{\partial S} < 0$.

Encroachment, EN, in the tank foreshore area lowers the storage capacity of the tank and reduces the tank water supply. Once encroachment occurs, conflict and water distribution problems among the farmers increase. The encroachment dummy variable should negatively affect yield, $\frac{\partial Y}{\partial EN} < 0$.

Tank type, TT, refers to whether or not a tank is dependent or independent. Since dependent tanks provide a more reliable irrigation water supply than the independent tanks they should produce higher crop yields. Thus, the dummy variable should have a positive sign, $\frac{\partial Y}{\partial TT} > 0$.

Water user organizations, WO, are farmer organizations which help allocate water in the tank command area when the water supply is inadequate. The water user organizations help resolve conflicts and improve the distribution of water among farmers. The water user organization's dummy variable should have a positive influence on yield, $\frac{\partial Y}{\partial WO} > 0$.

Channel structures, CS, represent the conditions of the channels for distributing water to farmers. Well maintained (satisfactory) channels mean that the water supply will be more certain and that the losses in transit will not be excessive. To capture this impact a dummy variable is specified based on the channel conditions. Channels in satisfactory condition should result in higher yield, $\frac{\partial Y}{\partial CS} > 0$.

Tank rehabilitation, TR, involves the lining of channels and/or the installation of community wells in the command area. These investments increase both the certainty and quantity of the water supplied. Thus, the dummy variable should have a positive sign, $\frac{\partial Y}{\partial TR} > 0$.

Most of the explanatory or independent variables included in the production function are statistically significant and have the expected signs (see Table 25). The $\bar{R}^2$ value of 0.98 indicated that 98 percent of the variation in paddy production is explained by the independent variables included in the model.

Among the independent variables, the coefficients are relatively high for tank water and well water. A one percent increase in the tank water and

Table 25. 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 one percent level

** significant at five percent level

* significant at 10 percent level

well water, ceteris paribus will increase paddy yields by 0.60 and 0.37 percent respectively. Similarly for fertilizer use and labor use, a one percent increase in these variables ceteris paribus will increase paddy yields by 0.01 and 0.09 percent respectively. The fertilizer coefficient is smaller than might be expected. This could be due to the over use of fertilizer or to its intercorrelation with the labor variable. Dummy variables such as the water user organizations and encroachment may also be picking up some of the variation due to fertilizer.

The negative sign on the cultural index may be related to its correlation with the asset variable, the two water variables and the labor variable. In fact, in the model without the cultural index, the asset variable becomes insignificant. These correlations tend to indicate that the better managers obtain more water and labor and have a high asset position. The negative correlation between sluice location and the cultural index suggests that better managers have obtained land along the lower sluices where they can obtain more tank irrigation.

The efficiency of input use at the farm level is indicated by the marginal value product (MVP) and opportunity cost of the inputs. The efficiency can be calculated as the ratio of marginal value product to opportunity cost. A ratio greater than one indicates under use of the input while ratio of less than one indicates overuse of the input.

The average cost of tank water is Rs 35 per acre or Rs 0.8 per acre inch. Normally farmers irrigate heavily when tank water is plentiful and under irrigate when the tank water is in short supply. Since the marginal cost of tank water to farmers is zero, they will tend to apply water until the MVP is near zero if the tank supply is adequate. Even when tank supplies are inadequate individual farmers do not have an incentive to conserve water. For if they do not use the water their neighbors will. However, group action has allowed farmers to save water during times of scarcity. If the farmers as a group use less water early in the season they can have some assurance that more will remain later in the season. In such cases the scarcity value of water to farmers should increase over the season until it is equal to the cost of pumping or the price of well water when the tank supply is almost exhausted. Thus there are some strong economic incentives for group action when tank water is known to be inadequate.

There are different costs for well water depending upon whether the water is from a farmer's own well or it is purchased from another farmer. In addition water from electric operated wells is lower cost than water from diesel operated wells while water from community wells is lower priced than from private wells. Thus the cost of well water varies among farmers and tanks. However, the opportunity cost should be based on actual resource cost for pumping water excluding taxes, subsidies and economic rents. Since it varies among tanks and farmers in the sample a range of costs are used (see Table 26). The average opportunity cost is probably fairly close to the cost of community well water.

Since fertilizer use is measured in monetary terms, the opportunity cost is 1+i, where i is the interest rate charged on capital. The average interest rate is 12 percent and hence the opportunity cost of fertilizer as measured by the cost of capital for six months is Rs 1.06. The opportunity cost of casual or hired labor is the current market wage rate for farm labor. The average market wage rate prevailing in the area for casual labor is Rs 5.67 per day.

Based on these MVP's and the opportunity costs, fertilizer appears to be overused while tank and well water are underused (see Table 27). Casual labor seems to be used fairly closely to the optimum rate. Most farmers applied

Table 26. The Cost or Price of Well Water, 1982

Source[a/]	Rate per hour (Rs)	Cost or Price[b/] per acre inch (Rs)
OE	0.90	1.80
HE	4.75	9.50
OO	1.90	3.80
HO	6.00	12.00
CW	2.25	4.50

a/ OE - Cost of electric operated farmer owned pump
HE - Price of water from electric powered pump
OO - Cost of diesel operated farmer owned pump
HO - Price of water from diesel powered pump
CW - Community well (electrically operated only)

b/ It requires an average of four hours to irrigate one acre with two inches of water. Therefore one acre inch takes two hours and costs (Rs 0.90) 2 hours = Rs 1.80.

fertilizers at rates above those recommended by the Department of Agriculture.[1/] On farms with assured tank water supplies, fertilizer applications were almost equal among farms and slightly higher than the recommended doses. Slightly higher than recommended fertilizer applications were also found on farms with inadequate tank supplies. Fertilizer applications were very common at the time of each irrigation. The farmers with uncertain water supplies claimed that it was important for them to keep the growth of the paddy crop in good condition by applying fertilizer every time they irrigated. The average amount spent on fertilizer per tank is highest in those with lowest paddy yields and the lowest tank water supplies; tanks 4, 7, and 8 (see Table 23). Thus the evidence, so far,

1/ The average rate of fertilizer application for paddy was 54:22:22 kgs of N:P:K per acre and the recommended doses by the Department of Agriculture was 40:20:20 kgs of N:P:K per acre.

Table 27. The Marginal Value Products and Opportunity Costs of Inputs, 1982

Input	Unit	Marginal Value Product (MVP) (Rs)	Opportunity Costs (OC) (Rs)	Ratio of MVP to OC
Tank Water[a/]	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 [b/]	acre inch	61.08	9.50	6.43
		61.08	12.00	5.09
		61.08	4.50	13.47

a/ The opportunity cost of tank water is calculated as follows:

$$\frac{\text{(cost of tank water X quantity of tank water used) + (cost of well water X quantity of well water used)}}{\text{(quantity of tank water used + quantity of well water used)}}$$

This method of calculation of opportunity cost of tank water is based on the assumptions: i) farmers use well water only when the tank water is not available, ii) farmers use well water when the tank water is exhausted, irrespective of the price of well water, since there is no alternative water supply and, iii) the value of tank water, when the well water is in use, is equal to the cost of well water.

b/ Taken from costs of well water discussed above.

suggests that too much fertilizer is being applied given the water available.

The high ratio of MVP to opportunity cost for tank and well water shows the effect of inadequate supplies of water on crop production. After paying the fixed and variable cost of the community well, the ratio of MVP to opportunity cost is still very high suggesting a high return from the installation of more community wells. If ground water supplies are adequate more private wells would also seem to have a high payoff in tank areas without adequate water supplies.

Dummy Variables

A shift in the intercept dummy variables implies a neutral shift in the production function. All of the dummy variables effect the production function in the expected way, i.e. had the expected signs. However, the coefficients for channel structures and water user organizations were small and insignificant.

In contrast the encroachment, sluice location, rehabilitation and tank type dummies were all large and highly significant. The encroachment and upper sluice location lowered the production function while tank type and tank rehabilitation shifted the production function upward. The downward shift in the production function due to encroachment and upper sluice location is caused by inadequate and uncertain water deliveries at the farm level resulting in lower crop yields. The average per acre paddy yield in tanks with encroachment was 200 kgs. lower than those without encroachment while the paddy yields were 317 kgs lower on farms served by the upper sluices when compared to farmers served by the lower sluices. The Dependent tanks had a higher production function than the Independent tanks resulting in a 600 kg difference in yields.

The higher yields in the rehabilitated tanks resulted from two alternative investments each with different potential returns. These alternative investments are channel lining and the installation of community wells. In one of the tanks studied, channel lining increased the per acre yields from 1296 kgs. to 1456 kgs. The installation of community wells in another tank increased the per acre yields from 950 kgs. to 1196 kgs.

Simultaneous Equation Model

Farmers' decisions regarding crop production are based on a number of variables which in turn affect the level of use of other inputs. This is particularly true in situations where the water supply is uncertain and not under the control of individual farmers. The availability of water directly influences both yield and input use which again affects yield. With this double affect of water on yield it is difficult to specify the relationship between yield and inputs in a single equation production function.

Parker and Bromley (1978) in their study of water distribution in Pakistan Punjab felt that a three equation regression model better explained irrigated crop production than the traditional one equation model. The first equation related water received by farmers to wealth and farm size, social status of the farmer, farm location, water laws and regulations, etc. The second equation related fertilizer applied to water received, farmers' willingness to change, availability of non-water inputs, etc. The final equation estimated wheat production based on water received, fertilizer applied, soil characteristics and the incidence of crop disaster. Because of the exploratory nature of the research, the authors used only simple linear regression models. Such models were only partly able to show the possible simultaneous effects of water on input use and yield.

In a subsequent study of irrigation in South India, Palanisami (1980) used a three stage simultaneous equation model to estimate irrigated crop production. The three equations in the model were very similar to the ones developed by Parker and Bromley. The only difference was that the equations were solved simultaneously. The results indicated that water availability was affecting fertilizer use and yield.

For our study of tank irrigation, a system of five equations is more appropriate than the three equation model. In fact even the five equation model is a simplification since several important variables are fairly constant across the sample. For example, all farmers in the sample used HYV's of rice and pest and disease problems were minor throughout the sample. Both variables could have involved separate equations in the model. In addition a management equation was not included because of estimation problems.

The five equations include four variables that were not included in the production function model. The new variables are: distance of fields from canal outlet, DF, number of wells, NW, the rice - well water price ratio, $\frac{P_r}{P_w}$ and the ratio of rice to fertilizer prices, $\frac{P_r}{P_f}$.

The distance of farmers fields from the main canal outlet is measured in kilometers. The farther a field is from the outlet, the higher will be the water losses due to unlined canals and intervening farmers. The distance will be negatively related to the amount of tank water reaching the fields $\frac{\partial TW}{\partial DF_j} < 0$.

The number of wells operating in a particular sluice, NW, will be key to determining the amount of well water available since the wells are about the same capacity. Wells tend to be concentrated in the areas served by upper sluices where the tank water supply is more limited. The greater the number of the wells, the larger will be the amount of well water, $\frac{\partial WW}{\partial NW} > 0$.

Since farmers are assumed to maximize their expected returns the higher the rice-well water price ratio the greater will be the quantity of well water used, $\frac{\partial WW}{\partial \frac{P_r}{P_w}} > 0$. A lower price ratio will discourage well water use because of the low returns from rice production.

The higher the price ratio of rice to fertilizer the more fertilizer that will be used $\frac{\partial F_j}{\partial \frac{P_r}{P_f}} > 0$. With higher rice prices the farmers will apply more well water and fertilizer. When farmers apply costly well water they also feel that applications of fertilizer are critical in obtaining the highest return. There are even some cases where farmers appear to be substituting fertilizer for well water late in the season.

In the first equation tank water availability or supply is a function of tank characteristics, field location, and farmer assets.

$$TW = f(S, EN, WO, TT, DF, A, TR, CS) \qquad (1)$$

All of the independent variables should affect tank water availability in the same direction as they did crop yield in the production function. For example, higher farmer assets should mean more tank water, $\frac{\partial TW}{\partial A} > 0$.

The second equation shows well water use or demand as a function of tank water, the rice - well water price ratio and the number of wells. The demand function is limited by the fact that in some cases well water could not or was not delivered even though the farmers were willing to pay a high price for the water. In such cases, well water was not delivered either due to other demands for the water (capacity constraint) or the farmer's location.

$$WW = f(TW, \frac{P_r}{P_w}, NW) \qquad (2)$$

The greater the amount of tank water the smaller the amount of well water that will be demanded. In contrast the other two variables should have positive coefficients. The number of wells, NW, is probably a good measure of the well capacity constraint. Variables for water users organizations, tank rehabilitation and distance from the outlet were included in an earlier model but were not significant in explaining quantities of well water.

In the third equation the amount of fertilizer demanded and applied per acre is a function of the two water variables, the rice-fertilizer price ratio and the farmer asset position.

$$F = f(TW, WW, \frac{P_r}{P_f}, A) \qquad (3)$$

All four variables should have a positive effect on fertilizer use. For example, the more water available from either source the more fertilizer farmers will apply within the limits of the crop variety.

Equation four explains casual labor demanded and hired in terms of water and fertilizer applied.

$$CL = f(TW, WW, F) \qquad (4)$$

Here the price ratio was not included because of the lack of variability among farmers in the wages paid for casual labor. The fertilizer input variables should have a positive effect on labor use while the water variables may have a negative effect. With more water, less labor needs to be hired for weeding and irrigation. On the other hand, more water means higher yields and a greater use of labor for harvesting. Thus, labor and water will be substitutes in some operations but complements in others.

The final equation is a production function with rice yields as a function of the four variables estimated in the other equations.

$$Y = f(TW, WW, F, CL) \qquad (5)$$

Greater quantities, up to a point, of all of the four input variables should increase the rice yield.

Results

In the model, rice yield, tank water, well water, fertilizer use and casual labor are endogenous variables and all other variables are considered as exogenous. The model is estimated using three stage least squares (G3SLS). In the five equations all variables have the appropriate sign and most are significant (see Table 28). Sluice location, encroachment, water user's organization, and distance of field from outlet are all significant in explaining the tank water available to farmers. In equation two for well water, all the variables, tank water, the rice - water price ratio and the number of wells are significant. The negative coefficient for tank water clearly shows the substitution of tank water for well water. For the fertilizer equation three, all the independent variables, tank water, well water, the rice-fertilizer price ratio and the asset position of the farmer are significant. In the casual labor equation four, the negative coefficients for tank and well water indicate that the increased supplies of water substituted for

Table 28. The Three Stage Simultaneous Equation Model of Rice Yield and Inputs, 1982.

Variables	Regression Coefficients	T-Value
EQUATION 1. Endogenous variable: tank water		
Sluice Location	-0.8640	6.51***
Encroachment	-0.2358	1.89*
Water user's organization	1.3364	12.79***
Channel structures	0.0485	0.46
Rehabilitation	0.0254	5.39***
Tank type	0.1276	1.03
Distance	-0.1427	2.69***
Asset	0.0366	0.54
Constant	-1.7295	2.60**
EQUATION 2. Endogenous variable: well water		
Tank water	-0.1389	6.04***
Number of wells	0.2664	10.94***
Input-output price ratio	0.2301	9.54***
Constant	-0.6103	7.98***

*Significant at 10 percent level.

**Significant at 5 percent level.

***Significant at 1 percent level.

Variables	Regression Coefficients	T-value
EQUATION 3. Endogenous variable: fertilizer		
Tank water	0.5876	11.38***
Well Water	0.4820	22.68***
Asset	0.1584	3.94***
Input-output price ratio	0.1478	2.83***
Constant	-1.6793	4.67***
EQUATION 4. Endogenous variable: casual labor		
Tank water	-16.9055	8.86***
Well water	-5.2152	5.12***
Fertilizer	18.6794	8.56***
Constant	-0.4255	0.16
EQUATION 5. Endogenous variable: rice yield		
Tank water	0.5385	8.22***
Well water	0.1437	4.55***
Fertilizer	0.6769	9.19***
Casual labor	0.0036	1.51
Constant	-0.0580	0.74

labor in the weeding and irrigation related activities. Continuously flooded fields require less weeding than those that dry out between irrigations. When water supplies were inadequate, considerable amounts of labor were utilized to weed the rice fields, clean the field channels, maintain the rotation schedules and irrigate the fields carefully with the available water. The reduction in labor used for these operations when water supplies were adequate or in surplus more than offset any increases in harvesting labor.

The tank water, well water, and fertilizer use variables are positive and significant in the production equation five. In contrast casual labor use, is not significant, probably due to overuse of labor. This is particularly true in cases where farmers ploughed, transplanted, and weeded the entire planted area before they discovered that the tank water supply was inadequate. As pointed out above 27 percent of the farmers had to abandon all or part of their planted area or apply water at a lower than optimum rate.

The efficiency in use of inputs, is reflected in the ratio of marginal value products (MVP) to opportunity cost of inputs (OC) (see Table 29). The ratio's are high for all three inputs indicating that they were being underused. This is particularly true for tank water. There also appeared to be room for expanding the use of fertilizer and well water particularly the lower priced community well water. However, other costs involved in the use of fertilizers and well water which are not included in the opportunity cost could move the ratios close to one. For example, the cost of applying fertilizer and well water was not included in the opportunity cost.

Comparison of Models

The most interesting difference between the two models of paddy production is the change in the relative size of the coefficients for the fertilizer and the water variables. All three are quite significant in both models but in

Table 29. The Marginal Value Products and Opportunity Costs of Inputs, 1982

Input	Unit	Marginal Value Product (MVP) (Rs)	Opportunity Cost (OC) (Rs)	Ratio of MVP to OC
Tank water	acre inch	27.20	1.94	14.02
Fertilizer use	rupees	2.89	1.06	2.58
Well water	acre inch	23.46	9.50 a/	2.47
		23.46	12.00 b/	1.96
		23.46	4.50 c/	5.21

a/ Cost to farmers of water from electric powered private wells.

b/ Cost to farmers of water from diesel powered private wells.

c/ Cost to farmers of water from community wells (electrically operated).

the simultaneous model the fertilizer coefficient is much larger while the water coefficients are smaller particularly the one for well water. This has a corresponding impact on the marginal products. For example, the fertilizer MVP is now above price of fertilizer or opportunity cost.

The water variables change production in two ways. First they influence the amount of inputs used particularly fertilizer and labor. Second, more water directly increases rice yields. Thus the water coefficients in the traditional production function model include the effect of water on yield as well as the effect of water on the amount of other inputs used.

The effect of the water variables on the labor and fertilizer variables can be seen from equations 2 and 3. Both water variables have a positive effect on the fertilizer, i.e., the more water available the heavier the fertilizer application. The opposite is true for the labor variable. Additional water reduces the amount of casual labor hired.

The simultaneous model makes explicit the manner in which the water limits rice production. In the traditional production function model the condition of the irrigation system, the organization of farmers, tank rehabilitation, encroachment and sluice location are shown as directly affecting the level of yield. However, the simultaneous model shows that these variables actually change the quantity of tank water available which in turn influences yield and other input use. Also the simultaneous model picks up the strong positive influence that water user organizations have on tank water availability while the single equation model does not.

Summary

Both models show the critical importance for rice production of adequate irrigation water supplies during years with normal or below normal rainfall. Farmers should be purchasing more well water and tank water if it is available as shown by the high ratio of marginal value product to opportunity cost, MVP_w/OC. Tank water supplies can be increased by reducing encroachment and by rehabilitating tanks. In addition tank and well water can be used more efficiently with the help of farmer organizations and improvements in irrigation channels. Curtailing encroachment and organizing farmers require institutional changes which will make it more difficult to encroach but easier to organize. Channel improvement and tank rehabilitation call for both public and private investment. In fact there is likely to be complementarity among these institutional changes and the private investment in tank systems. Farmer organization appears to foster improved channel maintenance and discourages encroachment. They do this by providing some assurance that the water saved by tank improvements will mean more tank water delivered to the farmers who have made the improvements.

CHAPTER VII

ALTERNATIVE INVESTMENTS TO IMPROVE TANK IRRIGATION

Reducing encroachment, desilting tanks particularly around upper sluices, community wells, channel lining and control structure improvements will increase crop production and farm incomes. However, determining the best methods for increasing the water supply and reducing the uncertainty of supply requires careful analysis. In the case of larger tanks rehabilitation depends on the irrigation department to decide which form of rehabilitation measures is the most effective for a given tank. The government can also increase the water supplies by subsidies for community wells or by providing credit for installing private wells. Other improvements such as lining the channels may also offer high returns in many locations. In this study we were only able to consider two types of improvements; channel lining and community wells. Further studies are needed to look at the full range of alternatives.

Channel Lining

The entire system of irrigation channels in the Piramanur Tank was lined by the water management division of the Agricultural Engineering Department. Private contractors installed the cement slab lining during 1979-80 at an estimated cost of Rs 294 thousand.[1/] Farmers are to repay the cost in 10 installments with an interest charge of 10 percent. Collections will start after two years of operation, i.e., 1983-84. The government pays 25 percent of the project costs since Ramanathapuram district comes under the Drought Prone Area Program.

1/ The slabs were made of 1:3:6 mixture of cement, sand and aggregate.

The Agricultural Engineering Department reported that the lining saved about 20 percent of the water which we judged to be a fairly reasonable estimate. Assuming that the annual storage in the Piramanur Tank of 290 mil. $ft.^3$ will continue, the saving in water will be about 58 mil. $ft.^3$ or 15,312 acre inches.2/ On an average this means that approximately 9.6 acre inches per acre of additional water is available due to lining. The value of water saved due to lining is equal to the saving in pumping cost for water replacing pumped water and the MVP of additions to the total water supply. Before lining, the wells provided on the average 8 acre inches per acre and the tank supplied 34.2 acre inches per acre. After the channel lining there was no well water used due to the additional tank water supplies (See Table 30). Thus only 1.6 acre inches can be considered as additions to the total water supply.

Table 30. Water Available in the Piramanur Tank Command Area.

Particulars	Tank Water	Well Water	Total Water Used
	----------------	acre inches per acre	----------------
Before lining	34.2	8.0	42.2
After lining	43.8	---	43.8
Additional water used	+9.6	-8.0	+1.6

2/ This is arrived based on the assumption that 1 mil. $ft.^3$ will irrigate 6 acres of paddy crop and one acre of paddy crop normally requires about 40-44 acre inches of water (58 x 6 x 44 = 15,312 acre-inches).

The total value of the 9.6 acre inches of water is Rs 73.6 per acre.[3/] To determine net returns, the value of this water must be compared with the cost of installing and maintaining the lining. The cost of lining per acre was Rs 213 based on actual government expenditure for the construction.

The internal rates of return (IRR's) are calculated for different lengths of life for the lining with and without maintenance of the channels. It is assumed that the lining will save tank water for up to five years if no maintenance work is done on the lined channels.[4/] However, a longer project life of 8 to 15 years is assumed when the lined channels are properly maintained either by the farmers or by the irrigation department.[5/] The IRR for a project life of five years is 14.3 percent. The IRR's with adequate

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3/ 1. Value of water saved in Rs per acre:

(a) saving in pumping costs is	8 ac. in. x Rs 4.5 =	Rs 36.0
(b) value of additional water is	1.6 ac. in. x Rs 23.5 =	Rs 37.6
	Total =	Rs 73.6

where Rs 23.5 is MVP of well water based on coefficient from the simultaneous equation model $(.54 \times \frac{1456}{43.8} \times 1.31)$.

2. Alternative value of water based on yield increase of 160 kgs. per acre due to the lining.

(a) Gross returns 160 kgs. x Rs 1.31 per kg.	=	Rs 209.6
(b) Extra production costs of labor Rs 10.3 and fertilizer Rs 11.6	=	Rs 21.9
	Total =	Rs 187.7

4/ At the time the effect of lining on yields was estimated, the project was completing its second year. Therefore, the 5 year project life is probably a conservative estimate for project life.

5/ Normally, the average maintenance cost per acre varies between Rs 6 and 10 and it involves primarily the maintenance of the structures above the outlet. The maintenance below the outlet is the responsibility of the farmers. However, because of the lining it is expected that the maintenance work will be done below the outlet by the irrigation department. Under such conditions, the maintenance cost per acre will be about Rs 20 annually.

maintenance are 16.6, 20.5 and 23.9 percent respectively for project lifes of 8, 10 and 15 years (Table 31). These returns which were based on conservative estimates of benefits, justify the investment made in lining. Hence, under conditions of water inadequacy and significant transit losses, channel lining seems to offer an attractive investment alternative.

Community Wells

Another alternative for increasing the water supplies to supplement tank water is community wells. The community well scheme is now operating in a number of tanks. The Drought Prone Area Program (DPAP) has helped promote the community well scheme with a 25 percent subsidy. The expenditure for the program is being shared equally between the central and state governments.

Table 31. Internal Rates of Return (IRR) for Channel Lining

Life of Lining (years)	Maintenance Charges (Rs/acre/year)	IRRa/ (percent)
5	-NIL-	14.3
8	20	16.6
10	20	20.5
15	20	23.9

a/ The formula used to calculate IRR is:

$$0 = \sum_{t=1}^{n} \frac{B_t - C_t}{(1 + i)^t}$$

Where B_t = benefit from lining in year t.

C_t = cost of lining in year t

i = internal rate of return or the discount rate which makes the net present value zero.

n = project life

The 100 tube well scheme, a special program under the DPAP, is also active in the district and the cost is shared equally by state and central governments. Seventy one tube wells out of the target of 100 have been installed under the authority of the district collector (DPAP, Project Records, 1981).

The community well scheme has been administered by the Panchayat unions but starting in 1980 the Agricultural Engineering Department has controlled the installation of the wells. After the wells are installed, the local Panchayat union is responsible for the operation and maintenance. The Panchayat union employs one operator for each well and it is the responsibility of the operator to distribute the water to the farmers who request it. The operator also collects the water charges from the farmers according to number of hours used and the money is turned over to the Panchayat union at regular intervals. The operators are paid from Rs 100 to Rs 150 per month. At present two community wells are successfully operating in the Rangian Tank (Tank 4).

One community well with 7.5 H.P. motor irrigates about 38 acres with a a total of 450 acre inches. The installation cost of the well including all inputs is approximately Rs 35,000 or Rs 921 per acre. The operating and maintenance costs are about Rs 2.25 per hour.[6/] Thus the cost of water to

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6/ The water charges include both operation and maintenance costs. Normally the cost of electricity and pump operations for one hour is Rs 1.78. The capital charges increase the cost per hour to Rs 2.25. The Panchayat union, which operates the community wells, sets the water charges.

farmers is (11.84 acre inches times Rs 4.50 per acre inch) Rs 53.2 per acre (see Table 32).[7/]

Table 32. Water Availability in the Rangian Tank Command Area

	Tank Water	Private Well Water	Community Well Water	Total Water Used
	---------------------- acre inches per acre ------------------			
Before community well	30.12	6.00a/	---	36.12
After community well	30.12	---	11.84	41.96

a/ Once the water from the community well was available the private well water was sold to a different group of farmers who had inadequate water supplies. Thus the net increase in water available per acre to farmers in the tank command area was 11.84 acre inches.

7/ If one assumes that the well operates 10 hours per day due to electricity shortages during February through April, the average running hours will be 90 x 10 = 900 hours. To irrigate one acre inch, about two hours are required. Thus about 450 acre inches of water are available or about 11.84 acre inches per acre. The 900 hours is a conservative assumption, as the well will also be operating during the months of May, June, and July to irrigate a second crop for a few farmers.

The gross benefits and cost per acre were higher for the community well than they were for the channel lining. The gross benefits to the village is the net increase in water times its MVP or Rs 219.4.8/ Because of the higher installation and operating costs, the net returns from the community well were slightly lower than for channel lining. However, the calculation of community well benefits does not include the benefits that occur to some of the farmers who irrigate a second crop. Another six acre inches was available for irrigation during the second season which would add approximately Rs 90 to annual benefits. This would substantially raise the IRR to above 20 percent assuming a 10 year life.

Even though the real internal rates of returns (IRR) are not quite as high as for the channel lining the community well investment offers a good rate of return of, at least, 12.7 percent after 10 years (see Table 33). The records of community wells also suggest that they will be in operation for more than ten years under normal conditions. Because community well water is lower priced than private well water, farmers use community well water when available and would like more community wells in other locations. However, if the community wells just replace private wells there is little or no savings to society.

8/ 1. Value of water based on the MVP in Rs per acre is 11.84 ac. inches times Rs. 18.53 per acre inch = Rs 219.40

2. Alternative value of water based on a yield increase of 246 kgs. per acre:

(a)	Gross returns 246 kgs. times Rs 1.31 per kg.	= Rs 322.26
(b)	Extra production costs of labor (Rs 41.60) and fertilizer (Rs 4.60)	= Rs 76.20
	Total	= Rs 246.06

3. The cost per acre of operating the pump is Rs 1.78 times 2 hours times 11.84 ac. inches = Rs 42.15

Table 33. Internal Rates of Return (IRR) for Community Well

Project Life a/	IRR b/ (percent)
5	-9.7
10	12.7
15	17.1
20	18.5

a/ The project life of the well is assumed to vary from 5 to 20 years. It may be possible to over exploit the groundwater with over pumping or the installation of too many wells.

b/ The formula used to calculate IRR is shown in Table 31.

Which type of rehabilitation will be best for a given tank will depend on a number of factors such as the availability of materials and farmer cooperation in maintenance. However, in the case of no water in the tank, investment in lining will not help. The installation of a community well depends upon aquifer characteristics, farmer cooperation in sharing the water and the electricity (power) availability to pump water regularly. Currently power availability is a critical constraint.

Channel lining will probably offer higher returns in big tanks while installing community wells are better in small tanks. For big tanks it is difficult to cover the entire command area by community wells. In addition the water storage area is large and channels are longer. Therefore the potential water losses are high and the benefits from lining would likely be larger. In the small tanks there are only one or two sluices which facilitates the installation of community wells at each sluice. Also the area served by one sluice is usually smaller in the small tanks and can be served by one well. Finally, small tanks generally serve only one village. Thus, it will be clear which Panchayat Union should operate and maintain the community well or wells.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

Tank irrigation systems are very common in South India, accounting for about one-third of the irrigated area. Most of these tanks are approximately 100 years old. The performance of these tanks are not satisfactory due to poor operation and maintenance. Many of the tanks have been neglected and lost much of their original storage capacity due to encroachment, siltation and inadequate maintenance. However, in the future, the importance of and concern for tank irrigation should increase due to constraints facing the development of groundwater and large scale surface irrigation.

To study the management of tank irrigation systems and to identify investment opportunities, Tamil Nadu Agricultural University and the University of Minnesota have been analyzing ten tanks in Ramanathapuram district of Tamil Nadu, with funding support from USAID. The first phase of the study indicates that seven out of the ten tanks have inadequate water supplies 50 to 70 percent of the years. Farmers depended heavily on the groundwater for supplementing tank water supplies. About one-third of their total water supplies came from wells. Most of the farmers served by tanks grow only one paddy crop. Farmers with inadequate water supplies adopted a network of strategies ranging from heavy fertilizer applications to a 4 to 7 day irrigation rotation to save their crops. This study identifies a number of key tank characteristics that affect the overall performance of tanks. These characteristics were related to the inadequate tank water supplies and the poor distribution of available supplies. Various alternatives must now be used to modify these characteristics so that irrigation performance will be improved and agricultural production increased.

Tank Characteristics

Encroachment

Cultivation of crops in the foreshore lands of the tanks is a serious problem limiting crop production in six out of the ten tanks. This became more serious after the sanction of Kulamkorvai Patta by Government in 1971, which confirmed the right of the farmers to cultivate in the foreshore areas. About 30 to 50 percent of the water spread area of the tanks is encroached on for cultivation resulting in a 30-40 percent reduction in tank storage capacity. In addition the encroachers illegally release tank water to avoid flooding of their crops. The penalty system to discourage encroachment is not effective and should be strengthened and enforced. There are acute conflicts between the command area farmers (ayacutars) and the encroachers, resulting in poor management of many tanks. Hence, it is important to reestablish the original foreshore area as indicated in the Tank Restoration Scheme (TRS) measurements. Heavy penalties and the withdrawing of the patta must be imposed on encroachers to help solve this perennial problem.

Sluice Location

Many of the tanks have upper and lower sluices to irrigate different portions of the command area. Due to poor maintenance, silt has accumulated in the tanks and seriously restricted water availability particularly for the upper sluices. In several tanks the upper sluices are functioning with less than 50 percent of their original water storage capacity. Hence there is a large disparity between farms irrigated from upper sluices as compared to lower sluices. The farms irrigated by the lower sluices received about 30 days more of irrigation for the crop season. To deal with this problem farmers must be organized and assisted in desilting tanks. Sluices should be restructured at appropriate places to serve more farmers. Finally, a program of watershed management needs to be adopted to help reduce future siltation.

Water User Organizations

Water user organizations only exist in tanks with continuing water shortage problems. The organization may be formal (sanctioned by the government) or informal. The tank operation and water distribution are more efficient in tanks with water user organizations. The maintenance of the tanks and channel structures is also better. The main purpose of some water user organizations is to bring additional supplies to the tank from other sources. Since the water is more equally distributed with user organizations, conflicts are reduced among farmers. The water distribution is not uniform in tanks without an organization, although the tanks may have adequate water for the crop season. Establishing farmers groups (formal or informal) is thus a pre-requisite for effective tank water allocation as well as tank maintenance. The irrigation, revenue and agricultural departments should all promote such tank based organizations with technical assistance for organizing. They also should make loans available to farmer organizations for making improvements in the irrigation system.

Tank Type

Normally tanks are classified as system and non-system tanks. However, this classification is no longer relevant for studying the performance of tanks. Many non-system tanks have adequate water while some system tanks have inadequate supplies. Therefore, a new classification is suggested, that of dependent and independent tanks. Dependent tanks are those with assured tank water supplies for at least one crop a year while independent tanks have inadequate tank water over 50 percent of the time. In most years the dependent tanks receive more water than required and farmers over-irrigate their paddy crops. Farmers in the independent tanks under-irrigate their crops and use wells to supplement tank water supplies.

Clearly investments to improve tank irrigation must be fitted to the type of tank involved. For the independent tanks the emphasis should be on saving water and increasing water supplies. Community wells and the lining of canals are two alternatives which offer potentially high turns. For the dependent tanks ways need to be found to transfer excess water supplies to other areas that have inadequate supplies.

New Tanks or Rehabilitation

At a higher level of decision is the question of whether to invest in new tanks or in tank rehabilitation. This question is important because of the renewed interest in the construction of new tanks and in improving the performance of old tanks.

Several new tanks were constructed in the last decade to provide irrigation to new lands. The economic feasibility of such investments was justified by high benefit-cost ratios. However, after construction, the tanks did not provide water to the full commanded area. At least 40-80 percent of the lands in the command areas was not irrigated. The major reason was the location of one or more sluices at a level lower than the fields to be irrigated. Under such conditions, it is difficult to irrigate the entire command area without pumping the water. Consequently the return from the tank investment is likely to be much lower than estimated and may not justify construction. In addition the best sites for tanks have already been used. This means that the expansion of new tanks will be constrained both by physical and economic factors. Thus, a very careful engineering and economic study must be made of all new tank proposals in Tamil Nadu. None should be built unless they pass the economic feasibility test.

The rehabilitation measures include a wide range of possible investments. Currently the Irrigation Department (PWD) is concentrating on measures to supplement tank water such as channel lining and community wells. Normally the water saving is about 20 percent from lining while one community or tube well irrigates about 40-50 acres. Our findings suggest channel lining should have a higher pay-off for large tanks while community wells (or tube wells) appear better suited for small tanks. Investment priorities need to be set by individual location and tank. Independent tanks should be given high priority for rehabilitation investments and farmers should be encouraged to organize to improve system maintenance and water allocation.

Further Research

The study indicates that relaxing the different tank management constraints along with the appropriate rehabilitation investments can provide a high rate of return. However, it is important to identify the tanks to be improved and to select the appropriate mix of management changes and rehabilitation investments. What we need is simple criteria to identify those tanks which offer the highest returns from various rehabilitation investments. To develop such criteria requires a wider survey to check the findings from this study. Based on our current study it appears that the criteria should include investment cost, construction time, farmers' willingness to cooperate, domestic water supply, potential fish benefits, potential recharge for wells, the level and variability in current production, hectares to be irrigated and potential for increasing yield.

The study quantifies the impact of water on yield and input use. In past studies the influence of expected water supplies on input use has been lumped together with the direct effect of water on yield. Making the water supply-input use relationship clear helps highlight the importance of information about water supplies. Farmers apply their inputs based on their expectations concerning water supplies. Improved information concerning water supplies should make these expectations closer to reality. When expected supplies are closer to actual supplies then input use will be closer to the optimum level. This in turn means yields and farm income will be raised.

More research needs to be done to determine the best method for estimating future water supplies and getting this information to farmers. Water user organizations (WUO) have in the past helped disseminate information concerning water supplies. However, are there other ways for farmers to determine what the likely supply will be, particularly if a WUO does not exist?

Additional research is needed on methods to improve tank performance. For example, should tanks, particularly those with substantial encroachment, be deepened by 20 or 30 feet. The increased dead storage could then be pumped out. This would reestablish the lost tank capacity while not causing a conflict with encroachers. In addition, the deeper tank would have less evaporation losses. However, the pumping and deepening cost may be quite high and must be compared to potential benefits to determine if this is a reasonable alternative.

Another possible improvement that should be studied is the rotation of tank irrigation among sluice outlets. The idea would be to coordinate private pumping and tank water releases and thus extend the period of tank irrigation. When a sluice is closed, pumps would be used in that area. While there is water in the tank, the water table is higher. Therefore, the longer water is maintained in the tank, the lower will be the pump lift and pumping costs. It would also allow a fuller irrigation of the command area. In a number of tanks the wells are not adequate to irrigate the whole command area. When the tank water is used up a number of fields cannot be irrigated. On the negative side, the longer water is in the tank, the greater will be the evaporation loss. However, on balance it appears that a larger area could receive an adequate irrigation if the tank releases and private pumping were better coordinated.

A careful analysis is needed of the forestry program in the tank water spread and foreshore areas. There appears to be potential benefits from reduced erosion, increased wood supply, and greater fodder supplies. Yet, if the forests use up irrigation water in the tanks, cause water pollution, and prevent farmers from desilting tanks then there will also be negative impacts. The ownership and distribution of the forestry products is also an important issue. Are the farmers involved in deciding where best to plant the trees and who should get the benefits? What land uses are they displacing with the forests. These and other questions should be asked before the program is expanded.

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APPENDIX I. Table 1. Seasonal Rainfall Patterns in Tirupuvanam (Sivaganga Taluk)

(Unit: mm)

Year	Southwest Monsoon Period	Northeast Monsoon Period	Winter Period	Hot Weather Period	GRAND TOTAL
Normal	344.2	386.0	53.8	145.5	929.5
1935-36	313.0	315.2	32.0	143.7	803.9
1936-37	250.7	343.1	8.6	188.3	790.7
1937-38	421.4	280.6	24.4	197.4	923.8
1938-39	652.2	194.3	39.4	120.7	1006.6
1939-40	345.8	351.8	--	286.2	983.8
1940-41	473.4	586.0	50.8	102.4	1212.6
1941-42	413.0	298.8	--	185.9	897.7
1942-43	369.6	517.1	133.0	152.4	1172.1
1943-44	300.2	353.8	57.1	92.7	803.8
1944-45	355.3	476.5	10.2	46.7	888.7
1945-46	216.9	325.6	3.8	242.6	788.9
1946-47	--	167.9	--	72.1	240.0
1947-48	122.4	264.4	60.5	32.8	480.1
1948-49	705.5	368.9	157.5	108.5	840.4
1949-50	365.6	153.0	126.0	39.6	684.2
1950-51	298.0	345.7	7.6	191.0	842.3
1951-52	489.0	352.6	89.7	76.7	1008.0
1952-53	230.7	202.1	35.6	188.7	657.1
1953-54	531.3	322.6	108.5	270.7	1233.1
1954-55	379.2	351.5	11.4	103.9	846.0
1955-56	336.6	689.4	40.1	49.8	1115.9
1956-57	468.3	303.3	--	--	771.6
1957-58	133.6	562.1	6.4	124.5	826.6
1958-59	241.9	306.5	41.9	116.6	706.9
1959-60	157.0	349.0	10.0	232.0	748.0
1960-61	469.0	525.0	Nil	117.0	1111.0
1961-62	266.7	279.6	24.2	115.9	686.4
1962-63	213.7	415.0	46.2	139.7	814.6

APPENDIX I. Table 1. (continued) (Unit: mm)

Year	Southwest Monsoon Period	Northeast Monsoon Period	Winter Period	Hot Weather Period	GRAND TOTAL
1963-64	342.6	383.6	--	84.1	810.3
1964-65	246.7	439.5	5.2	112.1	803.5
1965-66	424.5	199.3	48.0	10.1	681.9
1966-67	397.7	483.4	--	209.0	1090.2
1967-68	246.1	525.0	2.1	115.0	888.1
1968-69	182.8	337.0	6.0	76.0	601.6
1969-70	226.4	437.4	24.4	153.4	841.8
1970-71	460.4	329.8	--	126.4	916.6
1971-72	408.2	547.2	--	246.6	1195.0
1972-73	251.8	451.5	--	63.4	766.7
1973-74	324.2	601.6	10.2	16.0	952.0
1974-75	190.5	162.9	2.0	113.0	468.4
1975-76	138.4	530.0	2.8	198.4	869.6
1976-77	203.9	696.6	57.2	248.6	1206.3
1977-78	57.6	521.3	76.0	209.0	863.9
1978-79	212.0	894.2	36.0	60.2	1202.4
1979-80	102.8	424.0	--	246.8	773.6
1980-81	301.8	587.6	2.4	255.6	1147.4

APPENDIX I. Table 2. Seasonal Rainfall Patterns in Watrap (Srivilliputhur Taluk)

(Unit: mm)

Year	Southwest Monsoon Period	Northeast Monsoon Period	Winter Period	Hot Weather Period	GRAND TOTAL
Normal	145.8	502.1	80.3	182.2	910.4
1935-36	171.7	539.0	103.4	178.5	992.6
1936-37	151.0	755.2	81.5	277.7	1268.4
1937-38	299.7	727.5	185.2	194.4	1406.8
1938-39	241.2	181.4	27.9	200.9	651.4
1939-40	132.6	367.5	34.3	469.4	1003.8
1940-41	241.1	719.9	65.8	153.4	1180.2
1941-42	205.7	526.2	4.8	165.3	902.0
1942-43	107.3	656.1	268.6	292.6	1324.6
1943-44	134.3	449.1	78.0	348.8	1010.2
1944-45	343.1	747.8	9.1	374.7	1474.7
1945-46	18.8	532.7	12.7	295.6	859.8
1946-47	85.3	531.6	55.6	435.9	1108.4
1947-48	228.8	361.5	49.5	114.0	756.8
1948-49	191.8	499.7	32.7	167.7	891.9
1949-50	107.2	262.7	107.2	104.4	581.5
1950-51	102.4	319.5	18.5	202.5	642.9
1951-52	251.9	398.5	118.6	151.6	920.6
1952-53	30.0	392.5	80.0	115.2	657.7
1953-54	241.1	410.8	74.4	304.0	1030.3
1954-55	198.6	455.9	6.9	267.2	928.6
1955-56	93.8	578.8	34.0	75.5	782.1
1956-57	94.2	771.2	15.7	139.0	1020.1
1957-58	127.0	598.9	14.2	280.0	1020.1
1958-59	206.8	507.2	104.1	286.9	1105.0
1959-60	197.5	450.0	--	--	647.5
1960-61	232.1	455.8	114.0	155.6	957.5
1961-62	144.4	305.1	66.0	212.0	727.5
1962-63	251.5	532.4	24.0	356.0	1163.9

APPENDIX I. Table 2. (continued) (Unit: mm)

Year	Southwest Monsoon Period	Northeast Monsoon Period	Winter Period	Hot Weather Period	GRAND TOTAL
1963-64	37.6	695.5	--	118.3	851.4
1964-65	304.8	221.5	--	104.4	630.7
1965-66	81.3	432.3	--	103.9	617.5
1966-67	260.5	651.4	9.6	304.8	1226.3
1967-68	130.8	340.0	20.4	231.6	722.8
1968-69	158.0	333.1	--	155.0	646.1
1969-70	119.1	354.0	30.0	154.1	657.2
1970-71	16.0	360.5	21.0	148.0	545.5
1971-72	308.5	483.0	--	176.0	967.5
1972-73	97.0	445.6	--	223.0	765.6
1973-74	189.7	522.8	1.6	183.0	897.1
1974-75	123.6	418.8	28.8	121.8	693.0
1975-76	401.1	193.0	12.0	204.0	810.1
1976-77	129.0	904.5	12.0	30.0	1075.5
1977-78	316.0	390.1	38.0	195.4	939.5
1978-79	269.8	616.5	--	36.1	922.4
1979-80	270.5	308.5	58.1	67.6	704.7
1980-81	221.1	434.2	--	89.1	744.4

APPENDIX I. Table 3. Seasonal Rainfall Patterns in Sattur (Sattur Taluk)

(Unit: mm)

Year	Southwest Monsoon Period	Northeast Monsoon Period	Winter Period	Hot Weather Period	GRAND TOTAL
Normal	122.6	403.2	50.0	150.1	725.9
1935-36	183.2	256.8	14.0	217.9	671.9
1936-37	139.2	381.0	52.6	106.2	682.0
1937-38	129.0	309.3	54.1	140.9	633.3
1938-39	162.1	155.5	53.4	119.4	490.4
1939-40	103.3	268.3	--	165.1	536.7
1940-41	81.0	737.6	66.0	56.9	941.5
1941-42	94.7	323.3	--	129.3	547.3
1942-43	82.4	361.6	68.4	207.8	712.2
1943-44	71.2	342.7	26.9	234.7	675.5
1944-45	203.2	509.3	--	194.9	987.4
1945-46	101.7	273.8	17.0	180.0	572.5
1946-47	129.8	431.0	72.4	362.2	995.4
1947-48	54.7	434.1	77.7	133.3	699.8
1948-49	174.5	453.4	107.9	251.2	987.0
1949-50	242.5	300.7	215.4	85.3	843.9
1950-51	72.1	188.0	28.2	252.5	540.8
1951-52	115.4	313.5	62.2	80.1	571.2
1952-53	92.5	188.5	57.1	81.5	419.6
1953-54	115.2	442.5	116.1	73.1	746.9
1954-55	150.5	364.0	21.6	23.6	559.7
1955-56	125.5	431.8	9.1	131.1	697.5
1956-57	110.3	379.7	--	18.0	508.0
1957-58	352.1	569.2	38.6	163.6	1123.5
1958-59	99.0	130.5	59.6	102.8	391.9
1959-60	127.4	247.8	47.9	298.6	721.7
1960-61	216.8	317.0	79.4	67.1	680.3
1961-62	118.0	439.3	105.4	244.0	907.1
1962-63	155.9	346.6	59.5	187.0	749.0
1963-64	144.0	375.0	--	125.0	644.0

APPENDIX I. Table 3. (continued) (Unit: mm)

Year	Southwest Monsoon Period	Northeast Monsoon Period	Winter Period	Hot Weather Period	GRAND TOTAL
1964-65	258.0	303.7	--	157.1	718.8
1965-66	221.2	388.7	8.0	95.0	712.9
1966-67	330.0	568.0	--	167.0	1065.0
1967-68	235.4	395.0	20.0	274.0	924.4
1968-69	336.6	329.0	10.0	62.0	737.6
1969-70	272.0	326.3	62.8	217.6	878.7
1970-71	72.5	215.0	35.0	232.1	554.6
1971-72	138.0	706.7	4.6	194.2	1043.5
1972-73	153.4	471.2	--	117.2	741.8
1973-74	220.4	529.2	--	130.0	879.6
1974-75	126.9	161.5	19.2	127.6	435.2
1975-76	107.1	149.0	--	179.2	435.3
1976-77	90.6	351.6	48.1	110.9	601.2
1977-78	103.0	488.9	36.0	83.0	710.9
1978-79	53.8	84.8	92.8	38.6	270.0
1979-80	206.2	702.4	--	124.6	1033.2
1980-81	124.6	482.4	13.4	135.0	755.4

APPENDIX I. Table 4. Seasonal Rainfall Patterns in Aruppukkottai (Aruppukkottai Taluk)

(Unit: mm)

Year	Southwest Monsoon Period	Northeast Monsoon Period	Winter Period	Hot Weather Period	GRAND TOTAL
Normal	195.8	403.1	57.9	139.7	796.5
1935-36	125.8	232.9	5.8	158.4	522.9
1936-37	112.5	296.2	23.1	168.2	600.0
1937-38	185.9	324.3	22.1	131.8	664.1
1938-39	238.0	204.3	45.7	199.7	687.7
1939-40	64.3	413.0	0.5	241.5	719.3
1940-41	173.9	899.6	100.6	69.1	1243.2
1941-42	172.9	446.5	--	170.9	790.3
1942-43	194.6	535.4	125.9	176.2	1032.2
1943-44	196.4	478.0	37.6	133.9	845.9
1944-45	246.9	637.8	6.4	117.4	1008.5
1945-46	154.4	529.3	8.6	209.0	901.3
1946-47	193.5	694.4	110.0	358.6	1356.5
1947-48	238.7	269.0	88.7	33.5	629.9
1948-49	77.7	383.5	49.8	149.6	660.6
1949-50	384.6	249.7	166.6	57.1	858.0
1950-51	144.2	160.3	27.9	218.7	551.1
1951-52	214.8	265.2	88.4	65.9	634.3
1952-53	115.3	213.4	12.7	146.8	488.2
1953-54	220.0	323.6	139.5	191.0	876.1
1954-55	117.9	391.7	13.7	138.7	662.0
1955-56	141.2	481.6	75.2	43.2	741.2
1956-57	66.8	366.0	--	--	432.8
1957-58	177.5	437.1	12.8	43.3	670.7
1958-59	164.5	224.3	57.5	111.8	558.1
1959-60	142.9	339.0	2.6	213.7	698.2
1960-61	205.0	583.8	38.7	12.0	839.5
1961-62	149.4	346.1	6.0	91.3	592.8
1962-63	378.1	276.5	112.5	223.0	990.1
1963-64	272.2	396.8	--	117.0	786.0

APPENDIX I. Table 4. (continued) (Unit: mm)

Year	Southwest Monsoon Period	Northeast Monsoon Period	Winter Period	Hot Weather Period	GRAND TOTAL
1964-65	369.6	294.9	10.0	208.0	909.5
1965-66	324.5	280.4	13.1	121.8	739.8
1966-67	264.9	546.8	--	118.0	928.7
1967-68	152.8	435.2	--	183.6	771.6
1968-69	210.9	307.5	--	93.7	612.1
1969-70	163.0	307.1	23.5	251.2	744.8
1970-71	259.2	206.0	70.0	219.0	754.2
1971-72	136.3	652.1	10.8	163.7	962.9
1972-73	334.8	387.4	--	95.2	817.4
1973-74	266.5	575.2	22.2	92.0	955.9
1974-75	160.2	138.2	--	177.5	475.9
1975-76	81.7	313.8	39.9	111.1	546.5
1976-77	101.4	470.4	--	164.9	736.7
1977-78	58.0	316.4	39.7	105.3	519.4
1978-79	214.0	606.1	39.4	92.3	951.8
1979-80	110.5	437.0	81.6	31.5	660.6
1980-81	242.1	400.2	--	123.7	766.0

APPENDIX II. Production Function Analysis - General Model

The general model is written with rice output per farm, Y, as a function of inputs and characteristics of the tanks, j = 1 to 10, and farmers, i = 1 to 200.

$$Y_{ij} = f(L_{ij}, A_{ij}, FS_{ij}, F_{ij}, TW_{ij}, WW_{ij}, CI_{ij}, EN_j, TT_j, WO_j, CS_J, TR_j, S_{ij})$$

Total labor, L, in man days includes family and hired labor. The total labor days was obtained by converting all the male, female, and children in the family and hired labor into man days based on the ratio of 3:2:1 (children:female:male), which is the same ratio as their market wage rates. The paddy crop requires timely labor operations starting with transplanting and finishing with harvesting and threshing. In addition, tank irrigation and related operations require more labor if more water is to reach the fields. This includes labor for channel cleaning and maintenance.

Farmer assets, A, in rupees include the farm buildings, wells, irrigation structures and farm implements. A high asset position is likely to be related to greater influence in tank operation and management. If farmers have a relatively high asset position, they will have more influence on the distribution of the tank water supplies and higher yields.

Farm size, FS, in acres, includes land owned and leased in by the farmer. Large farms will likely have supplementary sources of irrigation from wells. Size is also directly related to the asset position and the influence of farmers in irrigation water distribution. Larger farms should have higher crop yields. Yet farm size was insignificant in the analysis and not included in the final models.

The rupee value of fertilizers, F, applied by farmers is a combination of Nitrogen, Phosphorus and Potassium. High yielding paddy varieties (HYV's) are fertilizer responsive and the farmers in the tank irrigated areas are growing only HYV's.

Tank water, TW, applied in acre inches depends on the distance a farm is from the supply channel, the farm location on the lateral or sub-lateral, the location of the farm on the upper or lower sluice, the number of intervening farmers on the supply channel, and the condition of the channel. As the distance from the farm to the supply channel increases, the water supply will be decreased. The farmers nearest the water source will irrigate to a greater depth than those at a greater distance.

The total well water, WW, applied in acre inches varies both by tank and farm. In some tanks farmers irrigated two to ten times with well water while in others no well water was used. The greater the amount of well water used the higher would be the expected yield. However, for some farmers non-use of well water means they have adequate supplies of low cost water from the tank.

The cultural index, CI, is based on the timeliness of farming operations and is used as a measure of management. This is a potentially important variable since farmers have to be very alert to the appropriate timing of cropping practices, in response to the unpredictable tank water supply.

The tank sluice location, S, is classified as either upper or lower. The farmers located in the lower sluices receive water over a longer period than the farmers located on the upper sluices. Although the upper and lower sluices were designed according to the topography when the tank system was constructed, the upper sluices are silted more heavily than lower sluices.

Encroachment, EN, in the tank foreshore area will lower the storage capacity of the tank. This reduces the water supply available for farmers resulting in lower yields in cases where the water supply is inadequate. Once the tank capacity is reduced because of encroachment, the resulting problems of water distribution among the farmers are more difficult. For example, field location and farm size differences will play a larger role in determining crop yields.

Tank type, TT, refers to whether or not a tank is dependent or independent. Tanks are classified as dependent tanks when they have an assured water supply from a perennial source such as a reservoir or a river. The independent tanks have only rainfall and runoff as an assured source of water. During inadequate monsoon periods, the independent tanks will not completely fill resulting in water shortages. Dependent tanks generally receive enough water to fill two or three times.

Water user organizations, WO, are farmer organizations which help allocate water in the tank command area when the water supply is inadequate. The water user organizations help resolve conflicts and improve the equity with which water is distributed. The differences in water delivery between head and tail ends are reduced.

Channel structures, CS, represent the conditions of the channels for distributing water to farmers. The farmers' water supply will be more certain if the channels are present and in good condition. Well maintained channels facilitate the flow of water without excessive losses in transit.

Tank rehabilitation, TR, involves the lining of the supply channels and/or the installation of community wells in the command area. Tank rehabilitation increases the paddy yield by increasing the certainty and quantity of the water supply.