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History and Economics of Tank Irrigation in Semi-Arid Tropical India

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Tank irrigation in India has fallen from a maximum of about 4.8 million ha. in 1960–70 to less than 4 million ha. in 1975–76. Formerly a source of relative stability, tank irrigation has become more and more unreliable and it is a source of increasing instability in agricultural production.

The major factors causing the decline of tank irrigation in extent and reliability include the following: favourable economics of alternative sources for minor irrigation are diverting investments away from tanks environmental degradation such as deforestation, overgrazing, erosion, siltation, etc., is related to increases in population densities beyond optimal levels for tank development; and lack of administrative structures inhibits appropriate repairs and maintenance of tanks, proper water control and general tank management.

In view of the expectation that rising energy shortages will in future make gravity irrigation relatively more favourable economically than most types of lift irrigation and in order to remove shortcomings caused by the present administrative structure, it is proposed to establish a Tank Irrigation Authority (TIA). Such a step would also help to offset the negative effect population density has on tank utilization. As an autonomous body, the TIA would provide the structure for improved tank management, through efficient water distribution, provision of feed-back on tank performance from water users to maintenance engineers, and introduction of a system of use-oriented water charges.

Key Words: Irrigation, Small dams, Tanks, Semi-Arid tropics, Water distribution

Introduction

Small water reservoirs behind earthen dams are called tanks in India. Tanks supply many villages with drinking water, but their primary purpose is for irrigation. Tank irrigation is an old established practice in most of the semi-arid tropical parts of India and of some other countries. In India, the monsoon rains fall erratically during a few months of the year, and irrigation tanks serve to store and regulate the flow of water for agricultural use. In southern India, this is primarily for the production of rice.

Development of Tank Irrigation Over Time

There is evidence that this technology of utilizing runoff water is deeply rooted in Indian culture and some tanks have inscriptions dating back a millenium of longer. Historians and anthropologists have pointed out that there is a dialectic relationship between population and tank irrigation, one reinforcing the other (Luden unpublished).

However, the relationship between density of population and the intensity of tank irrigation is not necessarily linear, i.e., at different levels of population density the growth of tank irrigated area may vary. Initially, where physically feasible and economically attractive, tank irrigation systems are expanded when the population density crosses a certain minimum level; tanks and population increase in mutual support to another level of population density, beyond which further population pressure may tend to adversely affect the existing tank irrigation systems, and special measures may be required to preserve the capital invested in irrigation tanks.

The historical data available for tank development in different states over the years, indicate that the threshold density to begin intensive tank construction lies between 50 and 60 persons/km² or 5 to 6 persons per 10 ha. The upper limit is not clearly discernible – it seems to vary from one region to another—but there is clearly a decline in tank irrigation. For instance, in India as a whole the absolute area irrigated by tanks increased from about 3.5 million ha. in the period 1945 to 1950 to over 4.5 million ha. in 1960 – 70; it fell subsequently to less than 4 million ha. from 1973 onwards (table 1), when rural population density in India increased to more than 135 persons/km². Population growth continues while tank irrigation decreases; at the same time canal irrigation and irrigation from wells has expanded rapidly.

The development of tank irrigation in India after independence was also subjected to other factors that may not be directly attributable to population density although they are related. Abolition of ownership rights for private tanks stopped private investment into tank irrigation soon after independence. This also decreased the efficiency in water control and tank management. On the other hand, public campaigns were launched to increase food production, and tank building was one of the activities vigorously pursued in such campaigns until the late 1950s. Subsequently, the availability of diesel- and electric-powered pumps made well water more attractive as an alternative, privately-controlled source for irrigation. Resources were shifted from the development of tanks towards wells, leading to a massive expansion of well irrigation. Further, reluctance from the policy makers to raise the water rates made it more and more difficult for the Public Works Department to acquire funds to cover increases in costs of maintenance and repairs. Tank irrigation, basically an economically productive and profitable undertaking, thus began to be neglected and was only half-heartedly supported by policy makers and planners. The resulting decreases in efficiency and in reliability of the performance of irrigation tanks tended to support an erroneous notion that tank irrigation is inferior to other types of irrigation.

Table 1 *Growth of tank irrigation in India*

Year	*Total cropped area*	*Net irrigated area*	*Well-irrigated area*	*Tank-irrigated area*	*Tank-irrigated area to total cropped area (%)*	*Tank-irrigated area to net irrigated area (%)*	*Well-irrigated area to net irrigated area (%)*
	(——— *In million hectares* ———)						
1950-51	131.9	20.9	5.9	3.6	2.7	17.2	28.2
1951-52	133.4	21.0	6.5	3.4	2.5	16.2	30.9
1952-53	137.5	21.2	6.6	3.2	2.3	15.1	31.1
1953-54	142.3	21.7	6.7	4.1	2.9	18.9	30.9
1954-55	144.0	21.9	6.7	4.0	2.8	18.3	30.6
1955-56	146.7	22.8	6.7	4.4	3.0	19.3	29.4
1956-57	149.1	22.5	6.2	4.5	3.0	20.0	27.6
1957-58	145.4	23.2	6.8	4.5	3.1	19.4	29.3
1958-59	150.8	23.4	6.7	4.8	3.2	20.5	28.6
1959-60	152.1	23.8	6.9	4.7	3.1	19.7	29.0
1960-61	152.3	24.6	7.3	4.6	3.0	18.7	29.7
1961-62	156.2	24.9	7.3	4.6	2.9	18.5	29.3
1962-63	156.8	25.7	7.6	4.8	3.1	18.7	29.6
1963-64	157.0	25.9	7.8	4.6	2.9	17.8	30.1
1964-65	159.3	26.6	8.1	4.8	3.0	18.0	30.4
1965-66	155.3	26.7	8.7	4.4	2.8	16.5	32.6
1966-67	156.8	27.1	9.2	4.6	2.9	17.0	33.9
1967-68	163.0	27.5	9.3	4.6	2.8	16.7	33.8
1968-69	159.7	29.0	10.8	4.0	2.5	13.8	37.2
1969-70	163.9	30.3	11.1	4.4	2.7	14.5	36.6
1970-71	167.4	31.4	11.9	4.5	2.7	14.3	37.9
1971-72	164.2	31.9	12.2	4.1	2.5	12.3	38.2
1972-73	161.5	32.0	13.0	3.6	2.2	11.2	40.6
1973-74	169.5	32.5	13.2	3.9	2.3	12.0	40.8
1974-75	163.9	33.7	14.2	3.5	2.2	10.5	42.1
1975-76	171.0	34.5	14.3	4.0	2.3	11.6	41.5

Sources: Government of India, Ministry of Agriculture, *Indian Agriculture in Brief*, various issues.

Factors Affecting Regional Distribution of Irrigation Tanks

Although runoff collection tanks exist in nearly every district of India, the density of tank irrigation varies considerably from district to district. Presently, in the semi-arid tropical region of India (figure 1), tanks are concentrated in South and Central India, i e , in the coastal districts of Tamil Nadu and Andhra Pradesh, in South-Central Karnataka, in Telengana and in East Vidarbha. In North India, there are two pockets that show a high density of tank irrigation: north-east Uttar Pradesh, in the area of the former kingdom of Oudh, and Rajasthan, east of the Aravalli mountain range. Apart from physical factors and population density it is believed that institutional factors also might have played a role in the past in determining the present distribution of tanks. A map showing the territory under British and princely rule in 1890 gives rise to the hypothesis that princely rule was more conducive than colonial rule to the promotion of tank irrigation (figure 2).

Factors affecting regional distribution of irrigation tanks were evaluated using

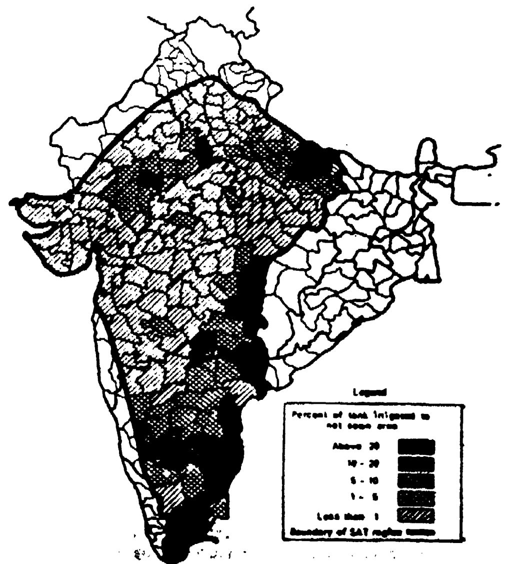

Figure 1 Density of tank irrigation in SAT India.

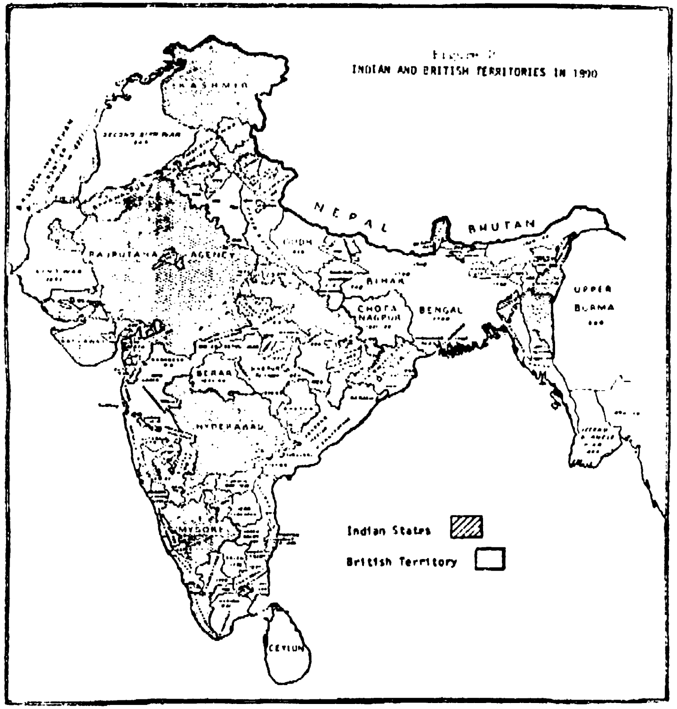

Figure 2 *Source:* C. Colin Davies, *An Historical Atlas of the Indian Peninsula*, Second Edition, Oxford University Press, Madras, 1976, p. 73.

data from 165 districts in semi-arid tropical India[2] in a regression analysis (von Oppen & Subba Rao 1980a).

This analysis showed that both in the former princely districts and the former British districts, physical factors, such as granite substrata, annual average humidity ... of rainfall distribution, low total rainfall and low moisture ... are conducive to tank irrigation and explain about

50% of the variation in tank densities. Furthermore, the study showed that in the former princely areas (but not in the former British areas) the influence of population density on tank irrigation was measurable, explaining another 20% of variation in tank density. Keeping all other variables constant the following was observed from this analysis: as population density in the former princely states passes the level of about 60 persons/km, density of tank-irrigated areas begins to grow reaching a maximum with population densities of around 120 persons/km² (figure 3) and dropping with further rises in population density. For the former British districts, no statistically significant relationship between population and tank density was found. These results imply that the institutional environment, to the extent that it differed between British and princely rule had an influence on construction and maintenance of irrigation tanks; in fact, this influence may still continue in the way in which local customs of water control, tank management, and repairs prevail.

Instability of Area and Production under Tank Irrigation

The observed decrease in tank irrigation with population increase from a certain "optimum" point of population density in the former non-British districts of India would seem to be related to another phenomenon, the increasing instability in tank-irrigated areas and production in certain regions of India. District analysis of the variability of tank-irrigated areas, using a moving coefficient of variation (MCV) over 8 years (moving from 1958-1965 up to 1968-1975), shows the following: in the districts of Telengana, e.g. in Warangal, the variability of tank-irrigated areas had earlier been well below the variability of rainfall, while in the later part of the period, during which rainfall variability remained at about the same level, the variability of tank-irrigated area went up considerably (figure 4). This observation is true also for districts in Rayalseema, e.g. in Cuddapah (figure 5), but not or not yet in Tamil Nadu (figure 6) (von Oppen 1978).

The increase in the variability of tank irrigated area is probably a function of physical as well as institutional variables, which are directly and indirectly related to population pressure (erosion, encroachment) and also attributable to changes in the institutional environment. After abolition of zamindari systems, tank management, organization, maintenance, repair, water control, etc. ceased in most cases to be under private control but became the responsibility of different bodies of public administration.

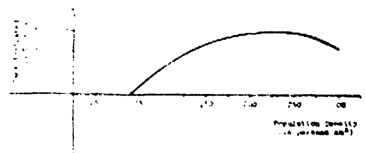

Figure 3 Tank Irrigation as a function of population density in formerly princely ruled districts in India. (Keeping physical factors constant)

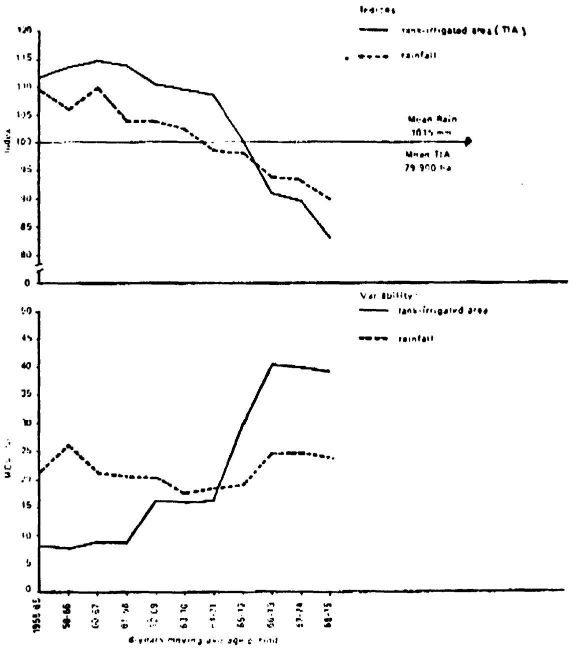

Figure 4 Indices (mean area and rainfall = 100) and variability of rainfall and tank-irrigated area, Warangal District.

The amount of money available to the Public Works Department for tank repairs has always been claimed to be insufficient for proper maintenance. Considering that the water rates the Revenue Department is receiving in the form of the difference between land revenue from dry land vs. wet land are only around 14 Rs acre of command area, the rate of maintenance expenditure can probably not be expected to be increased unless the water rate is increased. On the other hand, as the capital cost of an acre of command area is about 2000 to 4000 Rs. (say 3000 Rs) and maintenance rates range between 7 to 11 Rs/acre (say 9 Rs/acre) this amounts to only about one-third of 1% of the capital value, which from all practical experience in maintenance of capital goods is not likely to be enough.

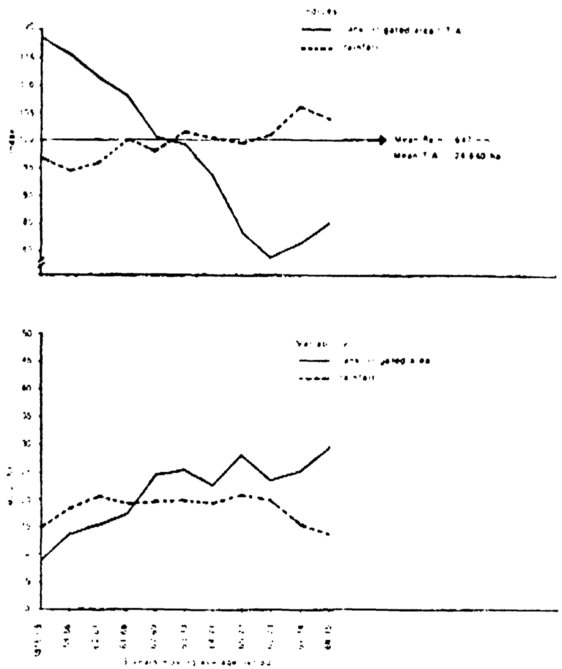

Figure 5 Indices (mean area and rainfall = 100) and variability of rainfall and tank-irrigated area, Cuddapah District.

In the past Zamindars, who collected up to 50% of the production under tanks, most likely spent a much higher amount on construction as well as on maintenance and repairs. Also, the provision that the same person was responsible for maintenance as well as revenue collection allowed for more direct reaction to urgently needed works than is possible in the present system—in which two separate Government Departments act separately on revenue collection on the one hand and maintenance on the other.

It is not known from direct investigation in which way the situation in Tamil Nadu differs from that in Andhra Pradesh; however, from accounts by others

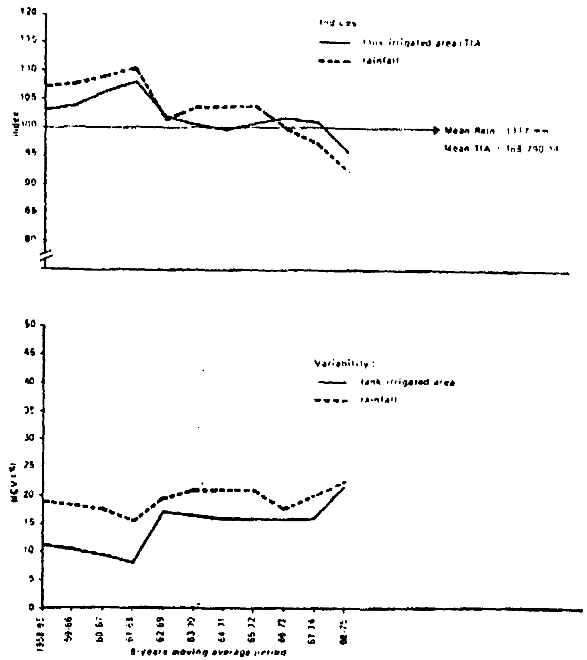

Figure 6 Indices (mean area and rainfall = 100) and variability of rainfall and tank-irrigated area, Chingleput District (Tamil Nadu State)

(Chambers 1977) it would seem that in Tamil Nadu the village tank is often regarded as a common good, with maintenance based on community action.*

A gradual "erosion" of the capital of irrigation tanks is the consequence. Construction of tanks todays is regarded as a welfare activity, and in the

*Kudi Maramath (cooperative repair work) is older than the British Administration. When the British began to administer Madras Province, they found that it was customary, in many districts, on the part of the village communities to contribute labour towards repairs of minor irrigation sources (*see* Baliga 1960)

field of minor irrigation, public decision makers as well as farmers and private entrepreneurs often pay more attention to the expansion of pump irrigation than to maintenance (not to speak of expansion) of irrigation tanks.

Measures for rehabilitating irrigation tanks are required. In view of the economics of tank irrigation (where it still exists and functions) and the potential productivity of this technology, such rehabilitation measures would have considerable payoff.

Economics of Existing Tank Irrigation

The costs and benefits of tank irrigation can be measured at several levels (table 2): (1) at the farmer's level, (2) at the level of the "Project Authority", responsible for construction and operation of the tank, and (3) at the national level.

Table 2 indicates the factors constituting the costs and benefits at each of these levels and the source of data available (or not available) (von Oppen & Subba Rao 1980b). The benefit-cost ratios at the farmer's level (table 3) indicate that compared

Table 2 *Comparisons of benefits and costs of irrigation tanks accruing to different participants*

Participants	*Benefits*	*Costs*	*Comparison Criteria*
I. Farmer	1. Private net returns at village prices due to irrigation**	1. Irrigation charges**	Financial cost benefit ratio
	2. Increase in land value**	2. Obligations to contribute labor†	
	3. Reduction in risk*	3. Uncertainty of water availability*	
II. Project Authority	1. Irrigation fees**	1. Land acquisition**	Financial cost benefit ratio
	2. Income from fisheries, brick making†	2. Construction**	
		3. Maintenance**	
		4. Water fee collection*	
III. Nation	1. Additional production at average prices**	1. Opportunity cost of capital invested (Interest)*	Economic internal rate of return
	2. Additional employment**	2. Submerged land*	
	3. Security in food production*	3. Higher water table† (Increased salinity)	
	4. Higher water table† (Increased groundwater)		
	5. Less soil erosion†		

*Indicates information from other sources is available.
**Indicates survey data are available.
†Indicates data or information are not available.

Table 3 *Farmer's private/direct benefits, costs and benefit-cost ratios (Rs/acre) in selected tanks of selected districts in India*

Tank code	Settled command area (Acres)	Net Returns: At village prices: Tank irrig.	Net Returns: At village prices: Rain-fed	Net Returns: At village prices: (3)/(4)	Net Returns: At average prices: Tank irrig.	Net Returns: At average prices: Rain-fed	Net Returns: At average prices: (6)/(7)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
AA	363	241	-19	241	409	-42	409
AB	719	206	186	1.11	394	186	2.12
BA	465	309	225	1.37	559	264	2.12
BB	161	546	61	8.95	794	113	7.03
CA	499	328	62	5.29	527	60	8.78
CB	257	650	1	650	824	9	91.5
DA	307	496	189	2.62	590	212	2.78
DB	242	840	207	4.06	922	228	4.04
EA	223	329	325	1.01	412	332	1.24
EB	163	774	170	4.55	832	160	5.20
MEDAK Average	340	472	141	3.35	626	142	4.40
FA	102	721	273	2.64	737	224	3.29
GA	290	960	329	2.92	953	276	3.45
GB	398	657	134	4.90	598	110	5.44
HA	736	531	140	3.79	609	55	11.7
HB	107	550	103	5.34	567	79	7.18
JA	103	705	52	13.6	884	57	1.55
KA	140	208	141	1.48	285	165	1.73
KB	161	380	102	3.73	506	103	4.91
LA	141	324	80	4.05	454	99	4.59
LB	147	325	174	1.87	620	183	3.39

Tank code	Increase in Land Value: Land value (Rs/acre): Tank irrig	Increase in Land Value: Land value (Rs/acre): Rain-fed	Increase in Land Value: Ratio (9)/(10)	Benefits: Net benefit due to tank irrig at vill prices (Rs)	Benefits: Net benefit due to tank irrig at av prices (Rs)	Costs: One season irrig fee per acre excl dry assessment	Benefit-Cost Ratio: At village prices	Benefit-Cost Ratio: At average prices
(1)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
AA	5400	1188	4.55	260	451	16.5	15.8	27.3
AB	6175	2010	3.07	20	208	12.5	1.6	16.6
BA	5340	1500	3.56	84	295	14.5	5.8	20.3
BB	5720	1670	3.43	485	681	14.1	34.4	48.3
CA	4200	1320	3.20	266	467	16.0	16.6	29.2
CB	8600	1750	4.90	649	816	14.0	46.3	58.3
DA	4750	1400	3.40	307	378	13.3	23.1	28.4
DB	4375	1350	3.20	633	694	15.8	40.1	43.9
EA	5000	2040	2.45	4	80	14.4	0.3	5.6
EB	5250	2050	2.56	604	672	13.0	46.5	51.7
MEDAK Average	5451	1628	3.37	331	474	14.4	23.0	32.0
FA	4417	1667	2.65	448	513	14.9	30.1	34.4
GA	5215	2125	2.45	631	677	14.7	42.9	46.0
GB	5500	2050	2.68	523	487	16.3	32.1	29.9
HA	4330	1820	2.38	391	554	12.2	32.0	45.4
HB	3833	1714	2.24	447	488	13.0	34.4	37.5
JA	5125	2025	2.53	653	826	13.9	47.0	63.5
KA	4165	1670	2.49	67	119	11.5	5.8	10.3
KB	4420	1870	2.36	278	403	14.5	19.2	27.8
LA	4000	1875	2.13	244	355	11.8	20.7	30.1
LB	4060	1720	2.36	151	437	10.9	14.8	40.1

(*Contd.*)

Table 3 *(Contd.)*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
MAHBUBNAGAR Average	233	536	153	3.50	621	135	4.60	4506	1854	2.43	283	436	13.4	28.6	36.3
MA	1112	587	307	1.91	691	336	2.06	9500	2000	4.75	250	355	16.8	16.7	21.1
NA	927	409	163	2.51	622	193	3.22	5000	1500	3.33	214	428	16.0	15.3	26.8
NB	442	402	202	1.99	669	191	3.50	5500	1610	3.42	200	479	16.5	12.1	29.0
ANANTAPUR Average	827	466	224	2.08	661	240	2.75	6667	1703	3.91	241	421	16.4	14.7	25.6
PA	319	439	141	3.11	650	146	4.45	5000	1450	3.45	298	504	13.5	22.1	37.3
QA	1067	665	389	1.71	812	435	1.87	6600	2100	3.14	276	377	13.5	20.4	27.9
KURNOOL Average	693	552	265	2.08	731	291	2.52	5800	1775	3.27	287	441	13.5	21.2	32.6
RB	1001	103	88	1.17	134	93	1.44	1000	1000	1.00	15	41	21.3	0.7	19.2
RB	1100	88	149	0.59	76	116	0.66	1063	na	na	—61	—40	25.2	0	0
SA	759	331	425	0.78	354	361	0.98	2500	2500	1.00	—94	—7	24.5	0	0
TA	425	348	348	1.00	353	348	1.01	5000	na	na	0	5	21.3	0	0.2
AKOLA Average	821	217	253	0.86	229	230	1.00	2390	1750	1.37	−35	0	23.1	0	0
UA	593	446	95	4.69	339	79	4.29	na	na	na	351	260	34.1	10.3	7.6
VA	484	53	−114	0.53	8	−114	8.00	na	na	na	53	8	13.5	3.9	0.6
VB	1779	517	59	8.80	531	46	11.5	na	na	na	458	485	18.8	24.4	25.8
SHOLAPUR Average	952	339	14	24	293	4	73	na	na	na	287.3	251	22.1	14.7	10.4

na = Not available

farmer's costs— the water fees he pays in one season of about 13 to 16 Rs/acre—his net benefits due to tank irrigation are about 20 to 30 times that amount. However, these benefits accrue only on actually irrigated areas, and there is an increasing probability that a particular plot will not receive irrigation. Even if therefore the benefits are discounted by an arbitrary 50% risk factor, the farmer's net benefits due to tank irrigation would still be of the order of 10 times or more of the water fees.

To the project authority (an imaginary body) the water fees paid by the farmer constitute its returns. In comparison to the annual costs (in terms of present value plus cost of maintenance) of 400 to 600 Rs/acre, these returns are almost negligible (table 4). However, one might argue that the capital costs of tank construction should be written off as most of the tanks were constructed long ago; and that only the maintenance costs should be counted.

It is not clear, however, what the appropriate costs of maintenance should be. For instance, in Andhra Pradesh the Public Works Department is being allocated an amount of about Rs. 10/acre; this implies only one quarter of 1% of the actual capital investment in the tank. By any standard, spending only about one-fourth of 1% of the value of any building or construction work implies almost certainly its progressive decay. For appropriate maintenance of relatively durable buildings, such as irrigation tanks, probably at least about 2% of the capital value would be required.

The total construction costs were compared with farmers' net benefits and the internal rate of return computed. This gives a measure of social returns to the nation (table 5).

This analysis of the social returns from tank irrigation indicates the variability in the performance of tanks. On the basis of average prices, about 15 of the 28 tanks surveyed produce internal rates of return above 5% and of those only 8 tanks produce internal rates of return above 10%. All tanks, however, show considerable employment effects, tank-irrigated agriculture employing about 2 to 5 times the number of work hours of rainfed agriculture on the same farms.

The Concept of a Tank Irrigation Authority

Tank irrigation in parts of India is presently decreasing in extent and reliability, despite the fact that it has the potential to be socially and economically beneficial: the question arises of how to ensure that the existing capital of irrigation tanks can be preserved and possibly expanded.

A "Tank Irrigation Authority" might ensure that conditions leading to productive activation and enhancement of the capital invested in irrigation tanks in India are fulfilled. Irrigation tanks—unlike canal irrigation—can easily be administered by involving local communities. Rather than putting anonymous bodies in charge of repairs and collection of fees, such as the Public Works Department and the Revenue Department, a state corporation representing a "Tank Irrigation Authority" could be established; this corporation would form "Tank Committees' with elected and appointed members from the farmers' community and representatives of Government bodies. The "Tank Committee" would employ "Tank Controllers" who have the authority to allocate and distribute

Table 4 *Costs and benefits to the Project Authority*

Tank code	Settled command area (Acres)	Cost: Total cost of bund (← in '000 Rs)	All other costs	Total cost of the project (in '000 Rs →)	Cost per acre of SCA (Rs)	Present value per acre cost assuming 22 years life at 10% interest rate	Total cost/acre incl. Rs. 10/acre maint and repairs (Rs)	Benefit: Revenue Collected per acre of SCA (Rs)	Benefit cost ratio (9)/(8)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
AA	363	1244	575	1819	5012	616	626	16.5	0.026
AB	719	1244	801	2045	2843	349	359	12.5	0.035
BA	465	1125	640	1768	3802	467	477	14.5	0.030
BB	161	453	286	739	4591	564	574	14.1	0.025
CA	499	813	667	1480	2966	364	374	16.0	0.044
CB	257	623	421	1044	4063	499	509	14.0	0.025
DA	307	660	483	1143	3722	457	467	[illegible]	0.028
DB	242	762	401	1163	4808	591	601	15.8	0.026
EA	223	540	376	916	4107	504	514	14.4	0.028
EB	163	866	289	1155	7083	870	880	13.0	0.015
MEDAK Average	340	833	494	1327	4300	528	538	14.4	0.027
FA	102	254	190	444	4354	535	545	14.9	0.027
GA	290	792	462	1254	4323	531	541	14.7	0.027
GB	398	724	580	1304	3276	402	412	16.3	0.039
HA	736	1298	806	2104	2859	351	361	12.2	0.034
HB	107	266	199	465	4348	534	544	13.0	0.024
JA	103	256	192	448	4352	535	545	13.9	0.025

(Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
KA	140	694	253	947	6765	831	841	11.5	0.014
KB	161	585	286	871	5409	664	674	14.5	0.022
LA	141	456	254	710	5040	619	629	11.8	0.019
LB	147	458	264	722	4913	603	613	10.9	0.018
MAHBUBNAGAR Average	233	579	348	927	4564	560	570	13.4	0.024
MA	1112	2258	889	3147	2830	343	358	16.8	0.047
NA	927	2904	866	3770	4067	506	510	16.0	0.031
NB	442	983	620	1603	3627	446	456	16.5	0.036
ANANTAPUR Average	827	2049	791	2840	3508	431	441	16.4	0.037
PA	319	790	491	1281	4031	495	505	13.5	0.027
QA	1067	1792	887	2679	2511	308	318	13.5	0.042
KURNOOL Average	693	1291	692	1983	3271	402	412	13.5	0.033
RA	1001	1237	882	2119	2117	260	270	21.3	0.079
RB	1100	1325	888	2213	2012	247	257	25.2	0.098
SA	759	1275	818	2093	2757	339	349	24.5	0.070
TA	425	713	605	1318	3102	381	391	21.3	0.054
AKOLA Average	821	1138	798	1936	2497	307	317	23.1	0.073
UA	593	1004	733	1737	2929	360	370	34.1	0.092
VA	484	823	655	1478	3053	375	385	13.5	0.035
VB	1779	2263	820	3083	1733	213	223	18.8	0.084
SHOLAPUR Average	952	1363	736	2099	2572	316	326	22.1	0.068

Table 5 *Social benefit-cost analysis of tank irrigation projects to the nation*

Tank code	At village prices		At average prices		Employment (Hrs/acre)		Addl. employment due to tank irrig. (Hrs/acre)	Proportion of tank irrigated employment over rainfed (6)/(7)	Net present worth (—in '000 Rs—)	
	BCR	IRR (%)	BCR	IRR (%)	Tank irrig	Rainfed			Village prices	Average prices
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
AA	0.42	0.9	0.71	5.5	527	187	340	2.8	—1077	—537
AB	n	n	0.68	5.0	570	146	424	3.9	n	[illegible]
BA	0.27	n	0.90	8.4	488	64	424	7.6	—1344	—189
BB	1.10	11.5	1.54	17.7	487	241	246	2.0	77	409
CA	0.96	9.4	1.68	19.6	841	326	515	2.6	—59	1,341
CB	1.91	22.8	2.36	29.2	750	230	520	3.3	974	1440
DA	0.21	n	0.31	n	626	125	500	5.0	—915	—815
DB	0.55	2.5	0.59	2.9	601	142	459	4.2	—532	—487
EA	n	n	0.14	n	402	139	263	2.9	n	—799
EB	0.46	0.8	0.52	1.8	729	140	559	5.2	—627	—587
MEDAK Average	0.54	2.1	0.93	9.0	602	174	428	3.0	—5679	—924
FA	0.81	6.9	0.90	8.4	411	160	251	2.6	—88	—45
GA	1.03	10.4	1.10	11.6	381	162	219	2.4	36	132
GB	1.20	13.4	1.12	12.0	386	124	262	3.1	268	158
HA	0.95	9.2	1.34	15.3	326	81	245	4.0	—111	744
HB	0.91	8.5	0.99	9.8	447	115	332	3.9	—44	—6
JA	0.88	8.1	1.12	11.5	473	73	400	6.5	—56	436
KA	0.04	n	0.08	n	492	67	425	7.3	—918	—885
KB	0.10	n	0.15	n	395	55	340	7.2	—795	—755

(Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
LA	0.34	n	0.49	1.3	313	77	216	4.1	—479	—367
LB	0.19	n	0.54	2.3	487	54	423	7.6	—598	—341
MAHBUBNAGAR Average	0.71	5.8	1.08	11.1	411	98	313	4.8	—2528	676
MA	1.57	18.3	2.04	24.0	506	159	347	3.2	1957	3359
NA	0.42	n	0.70	5.3	329	96	233	3.4	—2221	—1097
NB	0.32	n	0.77	6.2	354	90	264	3.9	—[illegible]	—[illegible]
ANANTAPUR Average	0.84	8.0	1.23	15.6	396	115	281	3.5	—1252	1799
PA	0.21	n	0.35	n	620	112	508	5.5	—1043	—854
QA	0.50	0.9	0.68	4.5	497	139	358	3.6	—1388	—879
KURNOOL Average	0.4	n	0.58	4.3	556	125	433	4.5	—2210	—1566
RA	na	na	na	na	267	276	—9	1.0	na	na
RB	na	na	na	na	230	344	—114	0.7	na	na
SA	na	na	na	na	423	368	55	1.2	na	na
TA	na	na	na	na	271	337	—66	0.8	na	na
AKOLA Average	na	na	na	na	298	332	—34	0.9	na	na
UA	0.43	0.5	0.32	n	2	197	48	1.2	—1005	—1212
VA	n	n	n	n	230	260	—30	0.9	n	n
VB	0.68	4.9	0.67	4.7	242	175	67	1.4	n	n
SHOLAPUR Average	0.43	n	0.42	n	239	211	28	1.2	—1046	—1079

Notes : Social rate of discount = 10%
Life period = 22 years
BCR = Benefit cost ratio
IRR = Internal rate of return
n = Negligible
na = Not available

water, advise on need for repairs and new construction works and identify water users for collection of fees according to amount of water used. The "Tank Controllers" would be transferred every 3 to 5 years to other locations (similar to market secretaries in some states).

Under such a framework tank irrigation can be a profitable and self-maintaining proposition if the following conditions are fulfilled.

Control of Water Distribution

The water-use efficiency of a tank depends largely upon water management. The more judiciously water is used and distributed during the two growing seasons, the larger will be the area that can be served from a particular tank. Even a high water-consumptive crop such as paddy covering the entire tank command area does not require the same amount of water day after day. Instead, the water flow needed varies with the growth stage of the crop and with weather and wind conditions. Theoretical calculations show that a tank in which a 'tank controller' allocates water optimally by taking these variables into account can increase its command area significantly.

Naturally, if crops are grown that require less water—such as groundnut, sorghum, cotton, etc.—the water-use efficiency can be increased still further. However, such a step to increase efficiency requires also considerably higher costs of more sophisticated water allocation; for instance, for irrigated rainfed crops and supplementary irrigation the entire canal system has to be physically designed so as to allow "flushing" of the whole command area within a few days when a dry spell occurs. Because of the larger and wider command area, longer channels are required which have to be lined and provided with adjustable outlets. Staff to supervise the flushing operation has to be provided during those days.

It is not likely that radical shifts away from paddy can be achieved easily, because of relatively high investment costs in physical and institutional terms. Instead, water allocation by a tank controller and a system of fixing water-charges according to actual water use might allow less extreme and therefore more feasible solutions, i.e. a change in land-use patterns, where perhaps the higher outer fringes of a command area would be planted to irrigated dry crops while the lower wetter areas are cultivated with paddy. Depending upon water availability from year to year, farmers could be induced to shift larger or smaller proportions to irrigated dry crops so as to make best use of the water and the land.

A solution has to be found that maximizes the difference between the increase in productivity due to improved water use efficiency and the costs at which such improved water management can be provided. This point, where marginal costs of improved water management are equal to its marginal benefits, is difficult to determine as it varies from year to year.

Preliminary model calculations using 70 years of daily rainfall to stimulate a water storage system have shown that for an average tank a simple rule of keeping the sluice closed on rainy days would increase the irrigated area by more than 20% and reduce by about half the number of years that the tank runs dry during the cropping season. It should be possible to implement such a simple control function by a public authority at relatively low costs.

Regular Maintenance and Repair

Any tank constitutes an artificial obstacle to a natural waterway and as such it is permanently subject to destructive forces which would eventually lead to its breaching and washing away, unless it is continuously repaired and well maintained. Thus tanks, as old as some of them may be, cannot be regarded as permanent and stable features *per se* (such as perhaps mountains on river beds).

To maintain irrigation tanks requires annual inspection and regular repair works. The amounts spent for repair have to be kept at levels sufficiently high to preserve the capital value of a newly constructed tank, which amounts to about 3000 to 4000 Rs. per acre of command area.

Revenue Collection and Tank Management

Water rates levied in the tanks under study amount to something in the order of 14 Rs/acre. These water charges are collected by the Revenue Department and amount to a tax drawn from people who own irrigated land. Whenever the Public Works Department comes (on five-year cycles) to work on the tank, this activity is financed out of the water rates previously collected. However, this link is too indirect to be understood by the farmer; moreover, political pressure is often needed to get repairs done and this further obscures the rationale in decisions guiding tank maintenance.

Instead, a tank controller could report annually the amount of work that needs to be done and, in the light of such reports, repair works could be carried out according to actual needs, keeping in mind also the potential revenue loss of a particular tank if it is left unrepaired. Such a rational system of repairs would be appreciated by the farmers.

No Cultivation in Tank Beds

Tank beds should be kept free from cultivation so that desiltation can be carried out in an uninhibited way; tank beds could be used for grazing or in the upper fringes to grow trees. Cultivation and the subsequent acquisition of ownership rights by individuals in tank beds is likely to lead to endless disputes over the water storage level to be reached, and thus has the overall effect of reducing the capacity of a tank.

Desiltation on Tank Beds

Under controlled erosion, the siltation of the tank bed will be minimized, but even then silt is likely to accumulate, which over time will reduce the effective storage capacity of the tank. Regular desiltation of existing tanks should be the responsibility of a public body. By digging the fertile silt and redistributing it on the uplands from where much of it probably originated, the value of these uplands could be upgraded, while the storage capacity of the tank would be restored.

Erosion Control

Catchment areas should be kept in a state that prevents soil erosive runoff. Natural vegetation on the one hand or artificial soil preparation on the other, including

bunds or broadbed and furrow cultivation combined with grassed waterways, are effective means to reduce the speed of the runoff.

Conclusions

Tank irrigation is an economically and socially profitable technology: but under present conditions of management tank irrigation is deteriorating rapidly. Extent as well as reliability of tank irrigation are decreasing

In view of this decay of valuable capital, the creation of an authority that would be responsible for revenue collection as well as repairs and overall tank management, including identification of water users should be considered. Under such a Tank Irrigation Authority it is logical that the farmers could be charged higher water rates, because hopefully a better service would be provided, upgrading the performance of irrigation tanks to the benefit of every individual.

The level at which these rates would be fixed largely depends upon political considerations. However, as a principle, the Tank Irrigation Authority should operate on a no-gain, no-loss basis similar to other state corporations. A detailed study of the legal and administrative feasibility of a Tank Irrigation Authority is underway.

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