TANK IRRIGATION IN SEMI-ARID TROPICAL INDIA

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M. von Oppen and K.V. Subba Rao[†]

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 in 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

A number of tanks with inscriptions dating back a millenium or longer provide evidence that this technology of utilizing runoff water is deeply rooted in Indian culture. Historians and anthropologists have pointed out that there is a dialectic relationship between population and tank irrigation, one enforcing the other. 1

However, the relationship between density of population and the intensity of tank irrigation is not linear. 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,

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¹For example, Ludden

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 of irrigation tanks.

The data available for tank development in different states over the years, indicate that the threshhold density for intensive tank construction to begin lies between 50 and 60 persons/km². The upper limit is not as 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; subsequently it fell 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 especially has expended rapidly.

The development of tank irrigation in India after independence was subject also to forces that may not be directly attributed 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.

Table 1. All India growth of tank irrigation

Year	Total crop- ped area (In	Net irri- gated area millio	Well- irri- gated area n hecta	Tank irri- gated area res)	Tank irri- gated area to total cropped area (%)	gated area	Well irrigated area to net irrigated area (%)
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. Resources were shifted from the development of tanks towards wells, leading to a massive expansion of well irrigation. Further, reluctance from the side of policy makers to raise the water rates made it more and more difficult for the Public Works Department to receive the funds for covering the increases in costs of maintenance and repairs. Tank irrigation, basically an economically productive and profitable undertaking, thus began to be negatected 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 the erroneous notion of tank irrigation being notoriously inferior to other types of irrigation.

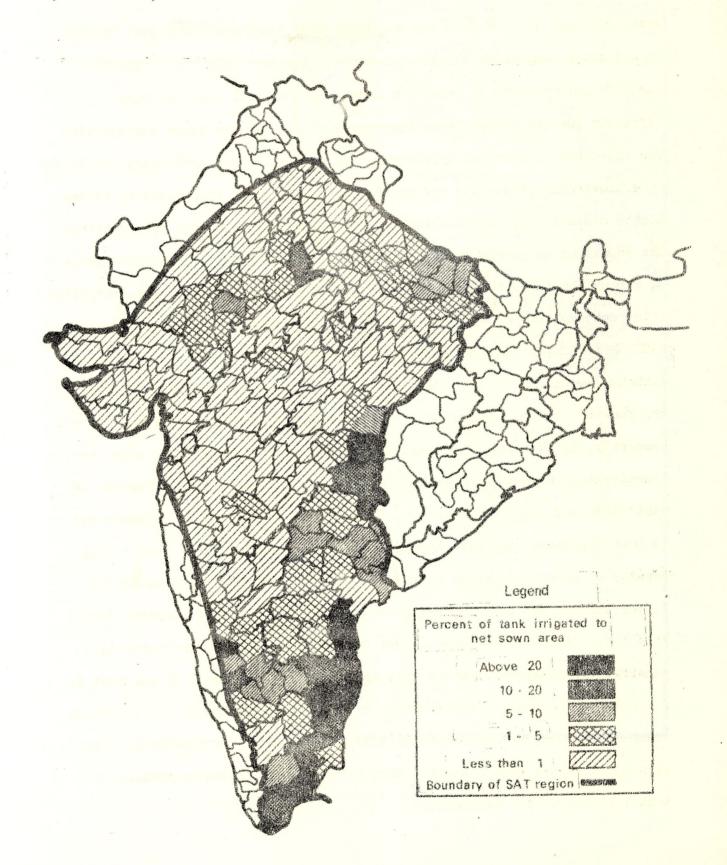
FACTORS AFFECTING REGIONAL DISTRIBUTION OF IRRIGATION TANKS

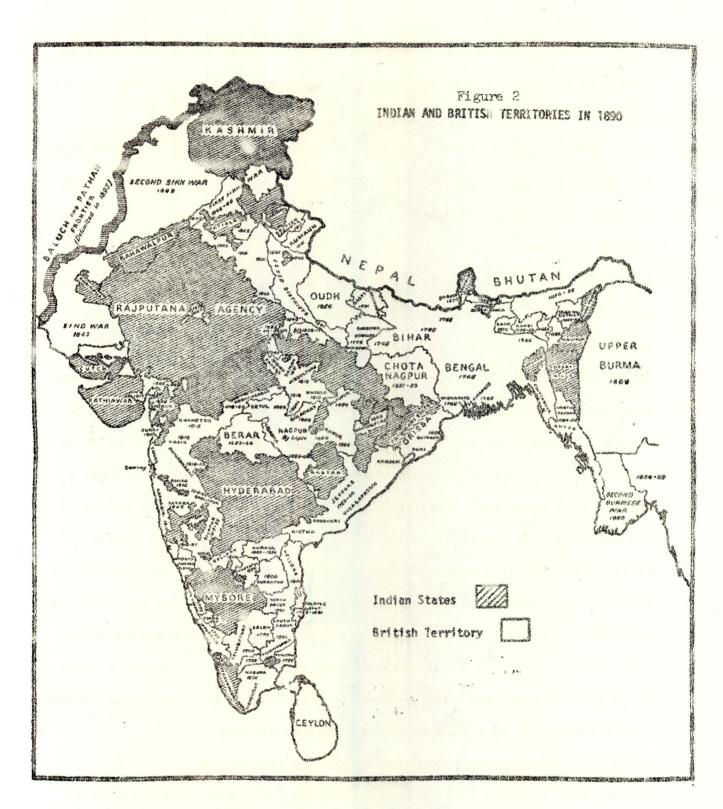
Although runoff collection tanks exist in nearly every district of India,
the density of tank irrigation varies considerably from district to district.

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 Telegana 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.

This leads us to believe that, apart from physical factors and population
density, 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 (see Figure 2).

Figure 1. Density of tank irrigation in SAT India





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

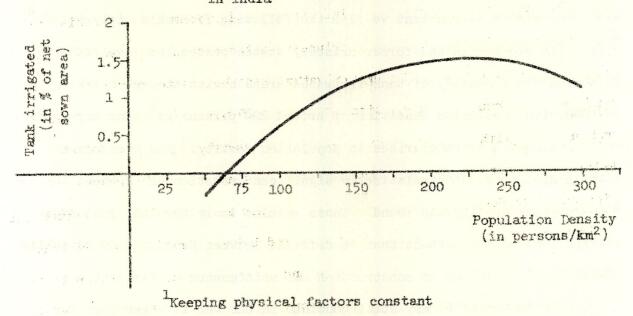
A test of the factors affecting regional distribution of irrigation tanks was carried out with the help of a regression analysis, using data of 165 districts in semi-arid tropical India.²

This analysis showed that both in the former princely districts and the former British districts, physical factors, such as granite substrata, humidity of the air, bimodality of rainfall distribution, low total rainfall and low moisture retention capacity of the soil all 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 we find the following from this analysis: as population density in the former princely states passes the level of about 60 persons/km², density of tank-irrigated areas begins to grow reaching a maximum with population densities of around 220 persons/km2 (see 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.3 INSTABILITY OF AREA AND PRODUCTION UNDER TANK IRRIGATION The observed decrease in tank irrigation with population increase from a

²For details see M. von Oppen and K.V. Subba Rao 1980.

³See also footnote 6, p. 13.

Figure 3. Tank Irrigation as a function of population density in formerly princely ruled districts in India



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).

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.

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

For details see M. von Oppen 1978.

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

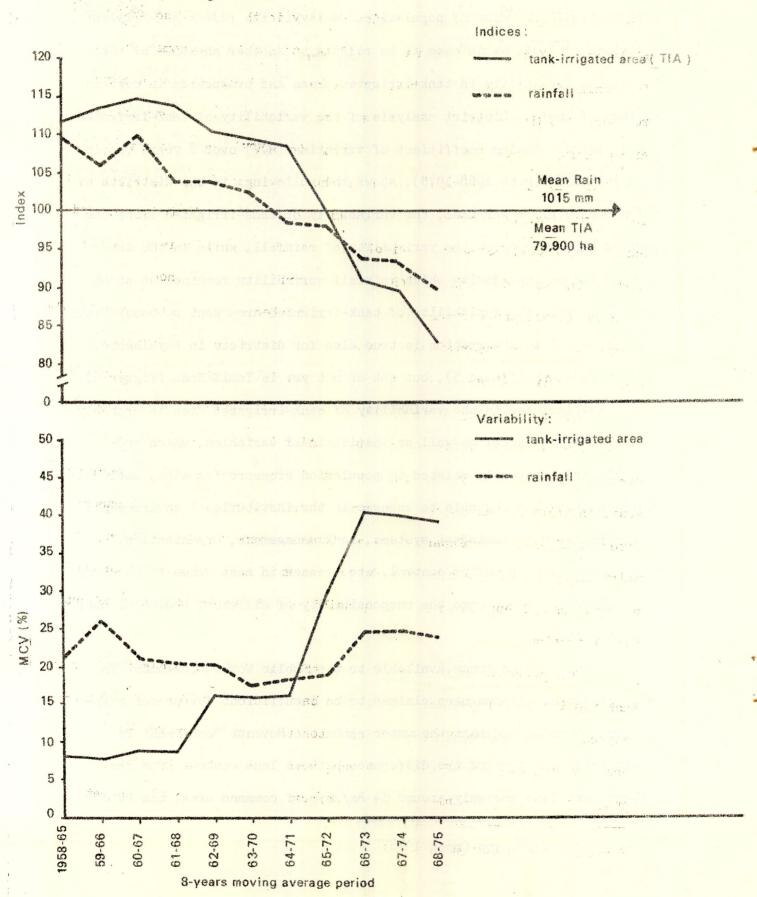
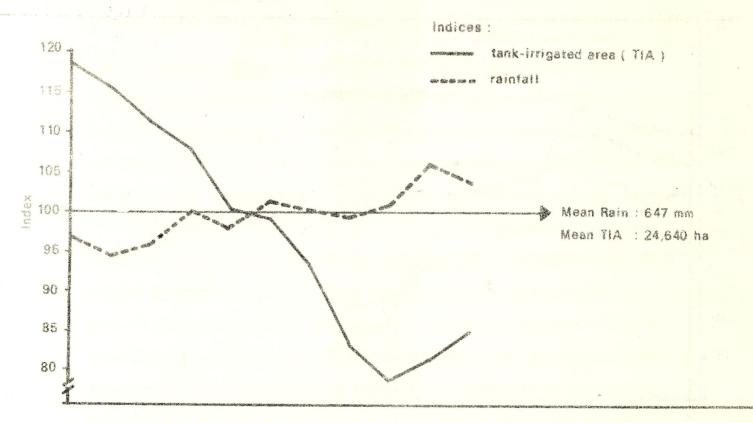


Figure 5. Indices (mean area and reinfall = 100) and variability 6' reinfall and tank-irrigated area, Cuddapah District.



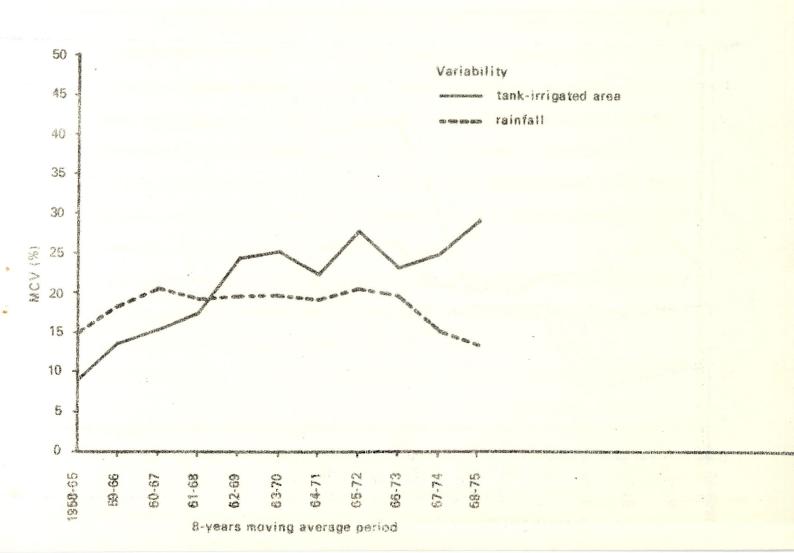
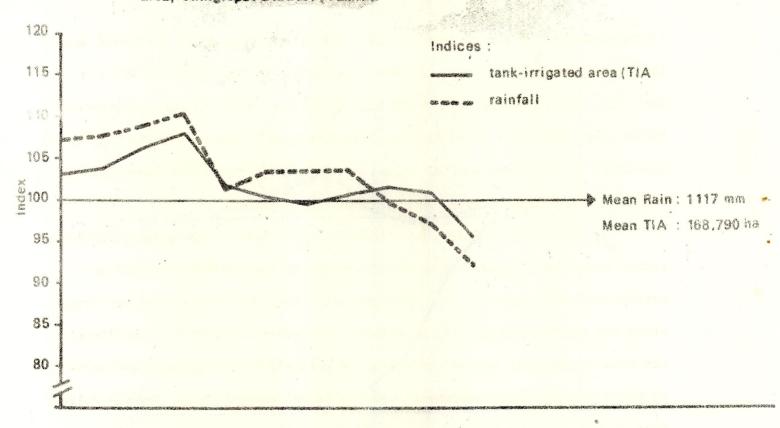
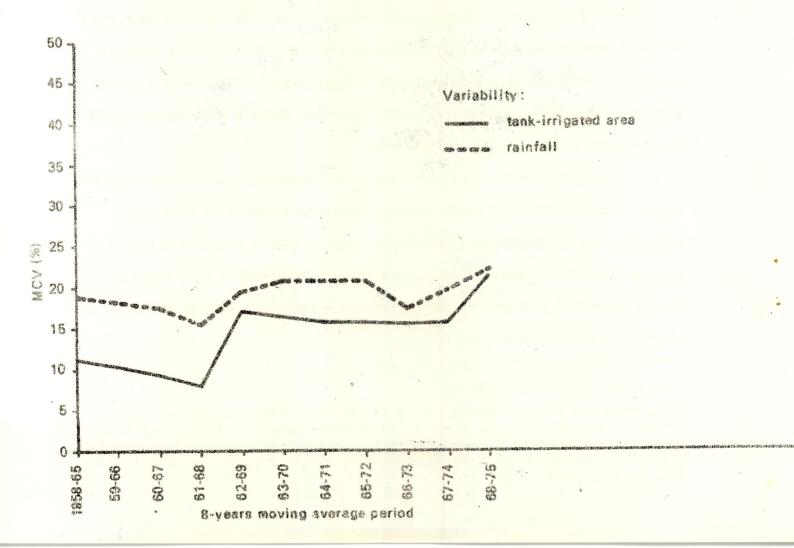


Figure 6. Indices (mean area and rainfall = 100) and variability of rainfall and tank-irrigated area, Chingleput District (Tamil b





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.

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 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 others⁵ it would seem that here the village tank in most cases would be regarded rather as a common good, with practices for its maintenance based on community action⁶ still in operation.

A gradual "erosion" of the capital of irrigation tanks is the consequence. Construction of tanks nowadays is being regarded as a welfare activity, and in the field of minor irrigation, public decision makers as well as farmers and private entrepreneurs are often paying more attention to the expansion of pump irrigation than to maintenance (not to speak of expansion) of irrigation tanks.

⁵For example, Chambers 1977

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 labor towards repairs of minor irrigation sources. See B.S. Baliga, 1960.

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 fo 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). The benefit-cost ratios at the farmer's level (Table 3) indicate that against 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 increasingly high probability for a particular acre to remain non-irrigated. 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 in 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 have been constructed long ago; and that only the maintenance costs should be counted.

⁷For details see M. von Oppen and K.V. Subba Rao 1980a.

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

Part	icipents	Renefits	Costa	Comparison Criteria
estina Ar	Farmer	1.Private net returns at villages prices due to irrigation** 2.Increase in land value** 3.Reduction in Risk*	1.Irrigation charges** 2.Obligations to con- tribute labor# 3.Uncertainty of water availability*	Financial cost/benefit ratio
1 thin a pile	Project Authority	1. Irrigation fees** 2. Income from fisheries, brick making	1.Land acquisition** 2.Construction** 3.Maintenance** 4.Water fee collection*	Financial cost/benefit ratio
nya nga mga nya nga mga nga nga mga nga nga mga nga nga nga nga nga nga nga nga nga nga nga nga nga nga nga nga	Nation	1.Additional production at average prices** 2.Additional employ- ment** 3.Safety in food production* 4.Higher water table* 5.Less soil erosion*	1.Opportunity cost of capital invested (Interest)* 2.Submerged land*	Economic internal rate of return

^{*}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), for tank irrigation

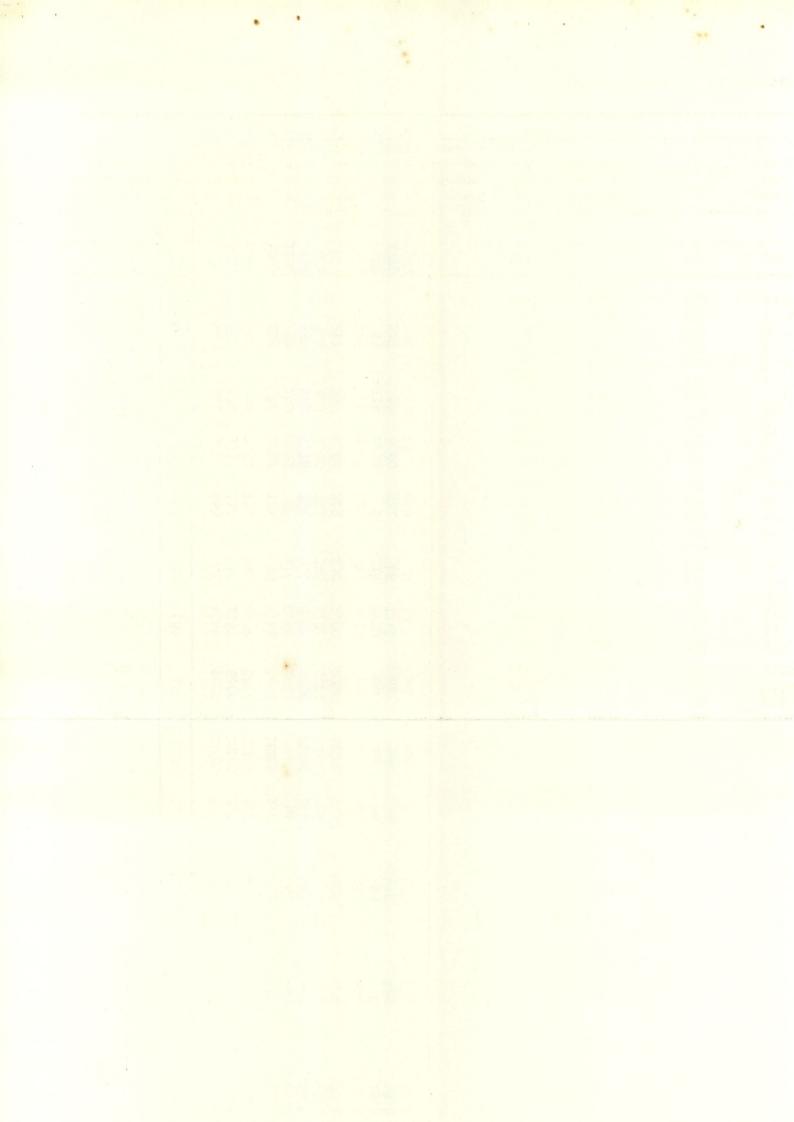
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Table 4. Costs and benefits to the Project Authority

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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.

If we compare the total construction costs with farmers' net benefits and compute the internal rate of return, we arrive at 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 of 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 of being socially and economically beneficial; the question arises of how to ensure that the existing capital of irrigation tanks can be preserved and possibly expanded.

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

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Notes: Social rate of discount = 10%
Life period = 22 years
BCR_Benefit cost ratio
IRR_Internal rate of return
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A "Tank Irrigation Authority" might ensure that conditions are fulfilled which lead to productively activate and enhance the capital invested
in irrigation tanks in India. 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 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 the water management. The more judiciously water is being 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 water manager allocates water optimally by taking these variables into account can increase its command area significantly.

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Naturally, if crops are grown that consume less water -- such as groundnuts, hybrid 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 during which the dry spell occurs. Larger and, because of the 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. land-use patterns, where perhaps the higher outer fringes of a command area are being planted under irrigated dry crops while the lower wetter areas are cultivated with paddy. Depending upon the 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 is equal to its marginal benefits, is difficult to determine as it varies from year to year.

Prelimi ary model calculations using 70 years of daily rainfall to simulate 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 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 was continuously repaired by hand 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 or 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 works that need to be done and, in the light of such reports, repair works should 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 OF TANK BEDS

Under controlled erosion, the siltation of the tank bed will be minimized, but even then silt is likely to be accumulating, which over time reduces the 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.

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In view of this decay of valuable capital, the creation of an authority that would be responsible for revenue collection as well as of 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 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 required.

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