

Sustaining Agriculture through Modernization of Irrigation Tanks: An Opportunity and Challenge for Tamilnadu, India

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Abstract

The importance of controlled water supply is indispensable for the sustainability in low land paddy production, which varies enormously from region to region and country to country. What essential is the degree of importance given to the three elements of water management namely (i) resource management within the watershed (ii) conveyance to the crop fields and (iii) management within farm fields. While water losses in the paddy fields are to be discouraged, they need not necessarily amount to the losses to the watershed as a whole, if they are converted into groundwater and pumped back to the surface. In India, the second largest rice producing country of the world, 80% of water is used for irrigation.. There are around 40,000 irrigation tanks in Tamilnadu, India, irrigating about 0.63 million ha of paddy fields. Whatever, the shortcoming at their creation, existing irrigation tanks remain as an asset to the sustainability of paddy agriculture in Tamilnadu, provided their live storage is not reduced and the related irrigation facilities are not deteriorated to serve the purpose. Past experiences show that availability of surface water resources are not always reliable, which has turned the paddy farmer's attention to the exploitation of ground water on a very much larger but manageable scale. The objective of this paper is to bring out the challenges and opportunities of the development strategies for the sustainability of paddy agriculture in the developing countries, (based on the experiences in Tamilnadu, India), where natural resources are plenty but financial resources are scarce. The performance of various types of small scale irrigation tanks in Tamilnadu are evaluated for their role in lowland paddy rice production, which lead to the invention of development strategies. These development strategies have both short term and long-term technical solutions. The short-term opportunities include on farm development works through modernization of existing irrigation facilities/structures and conjunctive use of surface and ground water resources. The long term challenge consist of establishing water grids connecting these modernized tanks in a chain to mitigate drought and flood at local level as well as encouraging the farmer's participation in planning and management of these irrigation facilities for sustaining the paddy agriculture. It was found that evolving a comprehensive but integrated modernization strategies for the tanks is a complex task, due to the dynamic interactions of water which is routed through catchment, tank and field levels as well as because of other pertaining land based issues. Initial evaluations of such integrated modernization approaches adopted through Pilot studies indicate better environmental and economic benefits, contributing for sustainable development of paddy agriculture.

1. Introduction

Over the last forty years world agriculture has been remarkably successful in increasing the food production. Greater output has been mainly due to improved land productivity, that is increased crop yield per hectare in Asia, although expanding the area in cultivation has been important in some areas, notably in Latin America and tropical Africa. Between 1955 and 1995, the area under irrigation grew from 100 M to 170 M ha. But the rate

of increase showed a fluctuating trend; from 1970 to 1989 it was 2.5 Mha/year, while it was reduced to 1.90 M ha/year in the last decade (Takamiya et al, 2000). This is largely due to increased constructions cost and lower commodity prices. As a result investment in the irrigation sector by the national governments and the major funding agencies has decreased. All previous works on analysing the potentials of sustainable paddy production assume that there is a substantial increase in crop yield in the future. For satisfying the future demand of increasing population, more than 10 billion in 2025, the present production of 525 M T rice has to be increased by 150% over the 25-year period (FAO, 1996). If past trends continue, some 95% of the increased output has to come from higher land productivity. World average rice yield will have to be rise from present 3.5 t/ha to 7.0 t/ha in 2025. Hence a balanced strategy for expanding irrigation to increase the crop productions is needed. But, there are few opportunities in the future than in the past, indicating very clearly that much efforts will have to put for improving the efficiency of existing irrigation systems for sustainable crop production in lowlands.

With competing demand for water, the quantities of water consumed by crops in an irrigation project are considerable. Also, the total volume of water handled by a irrigation project has to take account of system efficiency, a product of efficiencies during conveyance, distribution and field application. Typical figures of late projects in Asia would be 65%, 75% and 60% respectively, making the overall efficiency under 30% (Carruthers et al, 1997). Apparently there is much room for improvement through strategic modernization measures. While water losses on the farm fields are to be discouraged, they need not necessarily amount to losses as they recharge the ground water. Whatever the shortcomings at their creation, existing tanks as small scale irrigation resources should remain an asset to the sustainable paddy field agriculture in many Asian countries. It is an obvious fact that such problems cannot be solved on a project-by project basis, but have to be part of national sustainable agricultural development strategies, in which (i) resource management within the watershed (ii) conveyance to the fields and (iii) management within fields will be at the forefront. Experiences that tank water management was not reliable have turned the farmers attention to the exploitation of ground water resources, as a supplemental smaller and hence manageable scale.

The objective of this paper is to bring out the challenges and opportunities of the development strategies for the sustainability of agriculture in the developing countries, (based on the experiences in Tamilnadu, India). Discussions are focused to answer the following two questions (1) what are the potential returns from the tank modernization (2) how the challenges for benefits can be converted into opportunities for improved land and water productivity, through modernization measures, which at times are as important as environmental incentives and economic benefits in contributing for sustainable agriculture.

2. Crop Productions and Tank Irrigation in India

India has the world's largest harvested area under paddy rice crop, accounting for about 43 Mha and is the second largest producer of rice, with 97 M tons. It attained self-sufficiency in rice grain production, in late 1960s especially after the dissemination of high yielding varieties of rice. The key to feed the growing populations is increased agricultural production. But the net cropped area stabilized at 142 M ha, while the gross sown area averages at 180 M ha, giving an average cropping intensity of 127%. Thus there is no or limited possibility of increasing the net cropped area to an appreciable extent. Therefore increased crop production has to come from increased output from the same land. However,

the land productivity remains low, the national average yield being only 2.62 t/ha (FAO, 1996), nearly 26% lower than that of the world average. This is mainly because of limitation in availability of water during the critical months of crop growing season.

Nature has endowed this country with ample irrigation water resources, but has simultaneously posed a challenge by making their distribution highly uneven. Water scarcity is therefore considered to be primary factor limiting crop production in these areas. Therefore water storage becomes an essential component for sustainable crop production. Accounting for 37% of the paddy-cultivated area, tanks are the prominent mode of irrigation (Fig 1). Most of the rivers in this region are dry except during monsoon seasons and the flat gradients of the landscape do not offer many sites for building large storage reservoirs. In an average one third of the crop area is irrigated through tanks and hence their upkeep and modernization is the most important contributing factor for the sustainable development of agriculture.

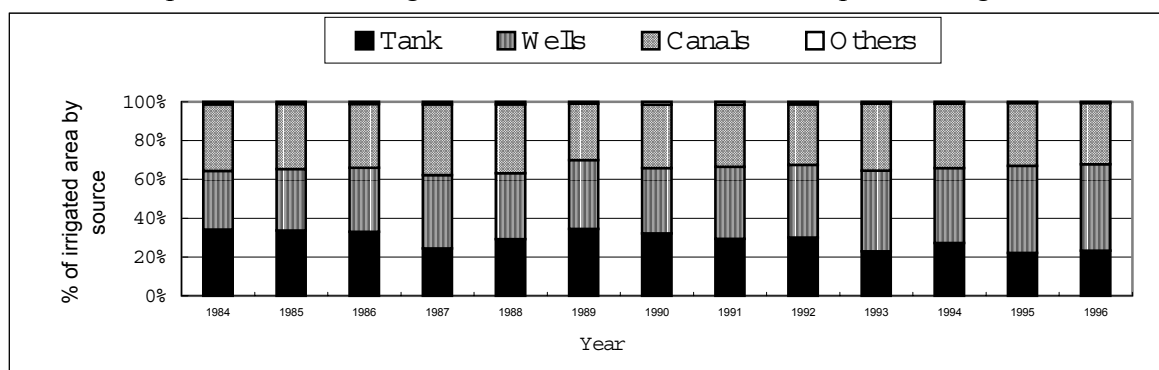


Fig 1. Area irrigated by different sources in India

Many agricultural and irrigation experts have begun to emphasize the importance of tanks (Hirashima, 1993; Mahendra Dev, 1988; Mohankarishanan, 1990; Tomita, 1991; Vaidyanathan 1989; Yamaji et al.,1995) and believe that tanks are important for water management and stressed the need for more efficient strategy to ensure water supply in drought year for sustainable crop production. Research results shows that if supplemental irrigation was available to crop in the command area of tanks, crop yield would increase by more than 1 ton/ha in tank irrigated area. Tanks would also be useful in reducing floods, recharging wells and providing drainage in high rainfall periods (Walter, 1963). The above points out the key role that tanks have played in irrigating the paddy cultivation areas. In many areas, tank irrigation is the only water source to harness rainwater and help farmers through crop growing period and provide stability to crop production. The underdevelopment, stagnation and even decline of agriculture in this region are usually attributed to their constraints in tank water supply. Without belittling the constraining irrigation infrastructures, these areas have significant production potential such as widely distributed well-drained clay loam soils, long hours of sunshine, that remains unutilized. Proper harnessing of the potentials and effective management of their constraints through modernization of minor irrigation tanks will ensure sustainable agriculture.

3. Components of Tank Irrigation System in Tamil Nadu

The term minor Irrigation Tank (MIT) or simply tank refers to a small storage reservoir raised to impound the runoff water from the monsoon rains, which occurs during a few months of the year. Although these tanks are widespread in India, the density of the tank

irrigation varies considerably from district to district (Fig 2). They are concentrated mainly in South and central India: in the coastal districts of Tamilnadu and Andhra Pradesh, in south central Karnataka. In north India, two pockets show a high density of tank irrigation; northeast Uttar Pradesh and Rajasthan. They commonly serve an irrigation area ranging from 5 ha to 400 ha.

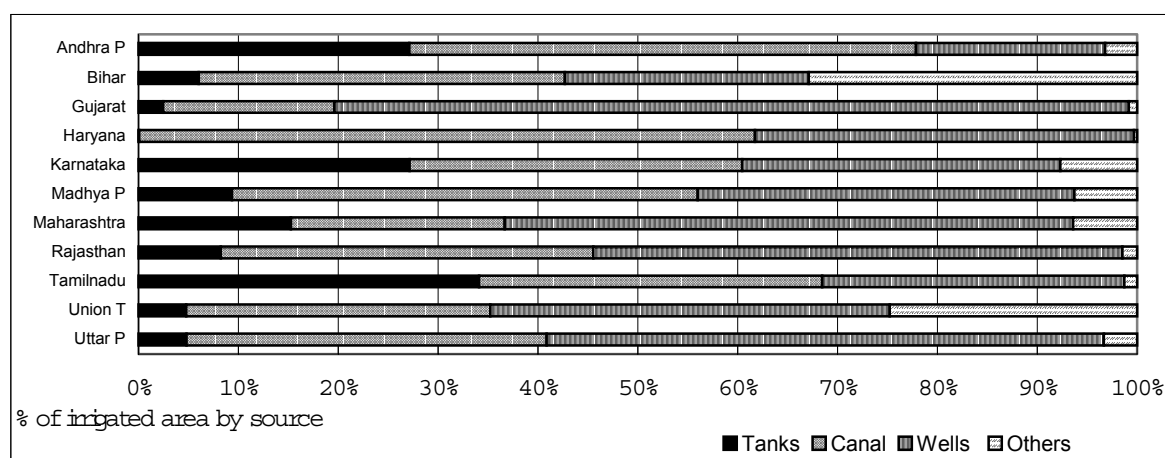


Fig 2. Intensity of Tanks irrigation in different states of India

The main components of the tanks are catchment area, water spread area and command area. The subcomponents are large earth embankments, sluices, surplus weirs and channels leading to field lots. The tanks fall under two categories 1) Rainfed tanks and 2) System tanks. In rainfed tanks, the rainwater falling in the catchment area is collected and stored in the water spread area and irrigates the command area. The system tanks, in addition to rainwater, receive their water supply from nearby perennial rivers through a system of canals into series of tanks situated as a chain along the river.

Tamilnadu, located in the southern most part of the Indian peninsula, is the state full of tanks. These tanks are generally classified as shown in Table 1. There are 39,202 tanks irrigating a net area of about 0.9 M ha (Table 2). Paddy rice accounts for about 77% of the total grain production of 7.98 Million tons. The average paddy yield is 3.17 t/ha. Crop water requirement for paddy in the monsoon in Tamilnadu state is calculated to be 550mm and rainfall in that period is 500mm, therefore, it is not possible to carry out secured paddy cultivation, under rainfed conditions and the irrigation is inevitable.

Table 1. Categorization of Tanks in Tamilnadu

Type	Command area	No. of tanks
1. In charge of Local Government		
a) rainfed small size	< 20 ha	16,477
b) rainfed medium size	20-40 ha	3,936
2. In charge of State Government		
a) rainfed tanks	> 40 ha	5,276
b) system Tanks	varying	3,627
3. Old Private Tanks	varying	9,886
Total		39,202

(Source: PWD)

Table 2. Area irrigated by different sizes of Tank in Tamilnadu

Command Area	No. of tanks	Gross irrigated area (ha)

a) < 200 ha	39,102	838,000
b) 200 – 280 ha	40	11,000
c) 280 – 400 ha	30	11,000
d) > 400 ha	30	40,000
Total	39,202	900,000

(Source: AED)

Moreover, Tamil Nadu has exploited almost 83% of the ultimate irrigation potential and has been utilizing the potential to an extent of 98.5% (Department of Statistics, 1997). This means that new irrigation works or project is extremely limited unless new additional water sources become available by inter-basin transfer, which could be secured by inter-state agreement. For new projects, this will naturally result in high cost per unit-irrigated area. Therefore, the remaining alternative is to conserve, manage and optimize the use of available water. This requires a conscious attention to modernize the existing tanks.

4. Performance Tanks in Crop Production

Bulk of these tanks are very old; they were built by ancient Kings hundreds of years ago. Their water use efficiency has come down to almost 25-30% in many cases (PWD, 1986). This is due to inadequate maintenance, operational inefficiency and lack of control over the regulation and excessive use of water at the field level. Because of these defects, the full contemplated command areas does not get the benefit and the net irrigation area has started declining, which is compensated by increase in the ground water utilization. In 10 out of 20 years (1975-1995), only 70% of the potential area is irrigated by tanks (Fig 3). The average utilization

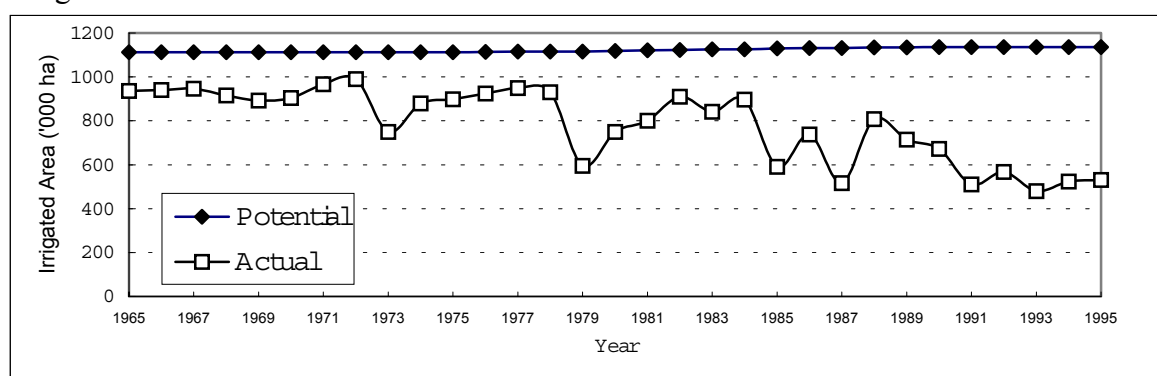


Fig 3. Area Irrigated by Tanks in Tamilnadu State

is only 63%, and this percentage is even lower for rainfed tanks, which account for more than 80% of the total area irrigated by all tanks. The constraints that impaired the irrigation efficiency of tanks and crop production in the tank command area are discussed below.

4.1 Tank Catchment Hydrology

As the area under crop cultivation is based on the capacity of the tank times the number of fillings, variation in rainfall pattern influences the storage quantity and irrigated area. From 1965 to 1995, the average annual rainfall in Tamilnadu was 764 mm with a coefficient of variation of 23%. One measure of water scarcity would be when the rainfall is less than 750 mm of average rainfall in the monsoon months of August to October. These were the years when tanks failed. The number of fillings in a year varies from 1.33 to 1.55, which is a function of rainfall and size of the tank catchment. The number of fillings has gradually decreased due to deteriorated condition of tanks. The first filling is expected

between August – September and the second in October – November. Any delay in getting the first filling will delay the planting of rice crop, which adversely affects the crop yield. Hence farmers, on the basis of their past experience, will be cautious in starting rice planting in years with low September rains.

Previous studies (DANIDA, 1995; Atkins, 1995) indicated that the catchment to command area ratios vary from 5:1 to 20:1. On an average, about 26 to 30% of the tank water spread area has been encroached by the farmers. These cause almost total interception of rainfall and reducing the supply to tank storage. The percent of the encroachment is found to be slightly higher for small tanks, as the ratio of command area to water spread area is relatively small. The ratio of the combined catchment area to the command area of 240 rainfed tanks varies from 0.31 – 0.39 km²/ha (JICA, 1997), which indicates that the location of tank in a chain of tanks affects the yield to a tank. Normally it is assumed that 20% of the yield of free catchment is available for subsequent tanks. In general tanks with assured water supply for crop cultivation, such as system tanks have lesser catchment area than the rainfed tanks. The same study found that there exist a close correlation between the tank capacity, catchment area and cultivated area. Many of these tanks have shallow catchment with large water spread area relate to command area (estimated in the ratio of 1:1.3). Evaporation losses are consequently large. The ratio between the free catchment to water spread area varies from 1.51 to 4.67, indicating the need for certain engineering solutions like raising the bund height, soil conservation measures in the catchment, reducing the evaporation loss by deepening the water storage area. In fact, storage of capacity of tanks is greatly reduced by siltation. It is estimated, on the basis of the government records that about 30% of the total tank storage have been lost in that way (GOI, 1994).

4.2 Structural Components of Tank System

The maintenance and repairs of many structural components of the tanks are poor. Almost all the tanks require repairs either in tank itself or in their components. Most of the irrigation tanks were constructed long time ago. After the declination of traditional maintenance system, no proper maintenance was implemented for the tank facilities including catchment treatment by farmers. For easy comprehension, the present constraints in tank improvement and the proposed modernization measures are summarized in Table 3. The water distribution system, especially sluices, is not properly operated because of poor maintenance and poor water storage in tank.

4.3 Field Water Management in Tank Command Area

Paddy rice is cultivated either as a single crop or double crop in tank command areas. To attain maximum field productivity, water must be supplied and regulated in such a way that maximum production could be obtained from the available tank water. This is not happening in the tank command area at present juncture. In fact, the lowest paddy yield per unit area in irrigated land is only from the failed tank irrigated lands (Sivanappan, 1982). A JICA (1997) survey on farm size of 240 elected tank command areas reveal that in an average 41- 66% of farmers possess land less than 1 ha. Medium size, 1 –2 ha farms vary in the range of 8-15%. Because of this, plot-plot irrigation is generally practiced and the farmers have not felt the need for better on-farm works. The dominance of small sized land holdings, high level of fragmentation as well as low returns to irrigation due to lack of each plot arrangement contemplates land consolidation, which will increase the effectiveness of water regulation.

Rotational system is widely adopted, with the irrigation interval varying between 4 to 7 days depending upon the soil, rainfall, crop and crop stage. Equitable and dependable supply at the right timings cannot therefore be ensured for individual holdings. Research findings have clearly indicated that it is enough to allow only 3-5 cm depth of water rice crop and the next irrigation will be after the water stored is completely depleted. In this way it is possible to save about 30% of water and yield will also increased substantially. By introduction this kind of water saving methods, it is possible to bring additional area under irrigated paddy and also expected to manage the available water on a sustainable basis.

Table 3. Constraints in tank irrigation development and required modernization measures

Component	Category	Constraints	Modernization measures	
Tank System Facilities	Tank	Catchment Treatment	<ul style="list-style-type: none"> • Soil erosion induced reduction in tank storage and tendency for silting up at intake points 	<ul style="list-style-type: none"> • Desilting of storage area and at intake points • Conservation of catchment through soil erosion control measures such as afforestation and terracing
		Tank Bund	<ul style="list-style-type: none"> • Insufficient top width and freeboard due to soil erosion of top level. • leakage 	<ul style="list-style-type: none"> • Restoration of top width and free board. • Reinforcement of bund top and slopes with lining.
	Intake and outlet Structures	Intake works	<ul style="list-style-type: none"> • Water leakage due to damaged shutters • Broken water control facilities such as Plugs and Barrels • Broken and damaged front and rear inlets and outlets 	<ul style="list-style-type: none"> • Provision of new slide gates and shutters • Provision of new plugs, plug rods and barrels • Reconstruction of inlets and outlets.
		Surplus Weir	<ul style="list-style-type: none"> • Insufficient length • Damaged leaky body wall and eroded rear protective works 	<ul style="list-style-type: none"> • Increase of length and modifications of crest shape to increase discharges. • Reconstruction and reinforcement of damaged works.
	Supply Works	Supply Channel	<ul style="list-style-type: none"> • Reduction of design discharge as a result of silting of channel • Deterioration of stone masonry channel • Insufficient flow velocity due to weed growth • Leakage 	<ul style="list-style-type: none"> • Periodical desilting of supply channel. • Reconstruction of damaged portion and strengthening at vulnerable sites. • Cleaning of vegetation in the channel.
Irrigation System	Distribution Network	<ul style="list-style-type: none"> • Slow movement due to obstruction by vegetation growth • Heavy seepage loss • Salt injury in inundated command areas due to channel leakage 	<ul style="list-style-type: none"> • Periodical repair of channel by Water Users Association. • Lining of main distribution channel • Proper maintenance of drainage channel 	
	Operation and Management	<ul style="list-style-type: none"> • Occurrence of non irrigated area due to insufficient water control structures 	<ul style="list-style-type: none"> • Lined channel with proper regulating and diversion structures at off-take points. 	
	Irrigation management	<ul style="list-style-type: none"> • Continuous over drawl without relevance to actual need, unofficial restoring subordinating equity to vested interests, small size plot-to-plot irrigation 	<ul style="list-style-type: none"> • Irrigation scheduling based on crop water requirements, cropping pattern and effective rainfall etc., land consolidation. 	

Farm Management	Cultivation Practices	<ul style="list-style-type: none"> • Reduction in farm profit due to inappropriate cropping pattern, cropping schedule • Crop injury due to continuous cropping and insufficient use of treated seeds, fertilizers, pesticides 	<ul style="list-style-type: none"> • Proper selection of cropping pattern and crop calendar to match with land use pattern. • Extension of new agricultural technology through Farmers' organization, optimum use of fertilizers and proper plant protection measures and provision of agricultural credits
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4.4 Conjunctive Use of Tank and Well Water

There are 1.6 M wells in Tamilnadu which irrigates about 1.2 M ha of crop area. Tamilnadu terrain is generally hardrock areas and during monsoon, large quantity of water is going as runoff and wasteshed. It is therefore necessary to modernize the tanks along with other water harvesting structures to augment ground water, Conjunctive use of ground water and tank water is also one of the important factors that influence the rice yield in tank command areas. In the non-system rainfed tanks, the dependency of well water is also high. The average number of wells vary from 10 - 22 in rainfed tanks while it is in the range of 8 – 14 in the system tanks, implying the inadequacy of irrigation water in rainfed tanks. From a detailed survey covering 566 tanks (Palanisamy et al, 1994), it was found that higher proportion of farms in tail reach are found to have supplemental irrigation than in head reach. They also found that rice yield was progressively higher with number of supplemental irrigation, than tank water alone. Also it was revealed that paddy yield is higher in tail reach farms with well irrigation than head reach farms without well irrigation. So, the conjunctive use of tank water and ground water should be considered in the integrated modernization program. In Tamilnadu, there is scope for developing about 887, 483 ha m of ground water resources by constructing another 478,789 wells in tank command area (PWD, 1994).

4.5 Farmers Organizational Framework for Water Management

Most of minor irrigation tanks are chained each other, and self catchment area of one tank is the command area of upper tanks, and both tanks are connected by the surplus or supply channels. Under these conditions, water distribution and tank storage operation need to be coordinated each other. There exist no such synchronized institutional framework within the present chained tank basin. After fading out of traditional maintenance system under the strong leadership, farmers lost their awareness that tank and irrigation facilities are their property. Water management below the tank cannot be viewed as purely technical one, since it encompasses essentially a social phenomenon and in the absence of its adequate understanding, methods of distribution and utilization of water are not going to be very satisfactory. Hence, the tank system has to be managed inevitable by the users themselves. Besides the effective and efficiency of the system depend on the involvement of the users only. Moreover management by a government agency will result in huge organizational expenditure too.

For easy understanding, a simple comparison of different factors that affect the paddy production performance is made in Table 3, which shows that they vary widely from system tank and rainfed tank.

Table 3. Comparison of crop production condition under different types of tanks

Basic Issues	System Tank		Rainfed Tank	
	> 40 ha	< 40 ha	> 40 ha	< 40 ha

1. Adequacy in water supply	Adequate	Adequate	Inadequate	Inadequate
2. Water users' association (informal)	No	No	Yes	Yes
3. Control over water release	Little	Little	Very high	Very high
4. Efforts to bring water to tank	Little	High	Very high	Very high
5. Ground water wells	8-14	8-14	10-22	10-22
6. Frequency of maintenance	More	More	Less	Less
7. Water distribution at plot level	Continuous	Continuous	Rotational	Rotational
8. Night irrigation	By few	By few	All	All
9. Conflicts in water sharing	Rare	Frequent	Occasional	Occasional
10. Current fallow after paddy crop	Nil	Low	Medium	Medium
11. Number of paddy crops	Two	One	One	One
12. Yield of paddy crop	3.96	3.95	2.48	2.76
13. Field Water Management	Plot to plot	Plot to plot	Plot to plot	Plot to plot
14. Fertilizer Use (Kg/ha)	97.2	95.7	78.5	70.0
15. Performance in paddy production	Satisfactory	Poor	Poor	Poor

These basic issues need to be considered and improvement measures have to be evolved in a comprehensive manner for sustainable crop production in all types of tanks.

5. Strategies for Sustainable Crop Production through Integrated Modernization of Irrigation Tanks

Above discussions, official data and academic studies prove that the tank based crop production system in Tamilnadu has been deteriorating over time. Though high yielding varieties and other modern inputs of farming are widely adopted, in respect of water use and water regulation the farmers in the tank command area still poorly informed and have not paid their attention. In order to sustain agriculture and to achieve the optimum utilization of the available water resources and maximum production per unit of water, these tanks have to be modernized in a comprehensive and holistic way. Such plans should, besides providing for large-scale repairs and improvements to the physical components (hardware) of the tank system also provide for better regulation of irrigation water and also capacity building of the farmers on optimum water use (software). An integrated modernization program with the following short term and long-term strategies can solve these problems.

- 1) Short term Opportunities on Maximization of Tank's Land and Water Resources
 - Modernization of irrigation facilities, such as bund itself, sluices, surplus weirs.
 - Selective lining of field channels in a systematic way on a priority basis, installation of measurement devices, and gate controlled diversion box.
 - Conjunctive use of water by installation of ground water wells at appropriate places to compensate for loss of tank storage and equity in water distribution to fields located in tail reaches of the tank command area.
 - Provision of drainage canals for plots and blocks.
 - Precise land levelling of fields.
 - Scientific water management at plot level.
 - Instituting strict land use guidelines such as choice of crop in the command area and soil conservation measures in the catchment area. These guidelines ought to be strictly enforced.
- 2) Long term Challenges on Management of Tank Resources
 - Remodelling of sluices structures.

- Transferring the water, wherever feasible from one sub-basin to another through systemization. Thus all supply channels, tanks and small percolation ponds can be linked so as to form a single water resource grid.
- Harvesting of early monsoon rainfall and using for rice nursery, which otherwise goes as waste by the established water grids connecting these modernized tanks in a chain.
- Implementing appropriate soil and water conservation practices in catchment, including afforestation, monsoon water harvesting techniques and good maintenance of supply channels to increase the water flow into the tanks.
- Integration of different uses of the tank water namely water based and land based uses. Among which, irrigation to paddy field shall be given the foremost priority.
- Consolidation of small sized land holdings for increasing the overall yield of first paddy crop in the tank command areas.
- Transferring management responsibilities to farmers' organization and better educating the farmers on scientific field water management activities. The policy should be that all tanks should have a water users' association whose powers and responsibilities are to be specifically defined. Formulation of individual water users association at individual tank level and a federation at watershed level will enhance the basin level water transfer. Alternatively, the government could establish a new tank management authority exclusively for tanks, or put all tanks under respective local governments.
- Motivation of farmers as beneficiary of tank common proprietor and for restoration of traditional self-help approaches.

Also, above discussions show that evolving a comprehensive but integrated modernization strategies for the tanks is a complex task, due to the dynamic interactions of water which is routed through catchment, tank and field levels as well as because of other pertaining land based issues. So, number of topics should be included in research program to address the modernization needs. More specifically, the need relates to identifying and analysing the static, dynamic and operational parameters involved in the tank performance, which affect the crop cultivation through modernization and renovation level.

6. Evaluation of Potential Returns from Modernization of Irrigation Tanks

By implementing the modernization program, it is expected that more than 25% of the water will be saved. Past experiences from a pilot project (CWR, 1996) shows that by physical (hardware) modernization alone, irrigation efficiency was improved by 32.25% and subsequently yield increased by about 30% as presented in Table 4.

Table 4 Comparison of benefits before and after modernization of an irrigation tank

Benefit	Before Modernization	After Modernization
Conveyance efficiency (%)	79.2	95.7
Distribution efficiency (%)	50.0	90.0
Application efficiency (%)	69.8	91.0
Irrigation efficiency (%)	27.7	78.4
Water requirement (m ³ /ha)	12,300	10,250
Paddy yield (t/ha)	3.025	3.933
Water Productivity (Rs/m ³)	0.26	0.32
Gross Income (Rs/ha)	2,962	5,261

(Source: CWR, 1996)

If such measures are extended to cover all other deteriorated tanks additional cropping area is certainly to be brought under cultivation, which will narrow down the gap between the potential and actual area irrigated by tanks. This along with improved land productivity through land consolidation and scientific water management will increase the total production of paddy rice. As shown in the above table, due to increased water productivity, private net returns to the farmer also get increased. Consequently, increased availability tank water will definitely reduce the risks in crop failure and as a result land value of agricultural fields will also be increased. Catchment treatment in the tank area will not only contribute for increased availability of water supply, but also bring such environmental benefits as reduced sedimentation and increased ground water recharge. Nevertheless, unlike major irrigation structures, modernization of these small-scale irrigation structures will not have any negative impacts on the environment at the same time ensuring the stability and sustainability of crop production in the tank command areas.

7. Conclusion

Tank irrigation is a profitable technology in economic, environment and social terms; but under present conditions of management it is deteriorating rapidly. Extent as well as reliability of this technology is decreasing. Because of potentials for additional rice cultivation for about 16 million ha under tank irrigation, it is important to select holistic improvement strategies that fully exploit the potentials of tank irrigation. In general, sustainable crop production requires better performance of these small-scale irrigation structures tanks, which needs (i) modernization of physical structures (ii) efficient distribution of water to and in farm fields as well as among the farmers (iii) proper maintenance of tank system after the modernization through farmers participation.

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