

Climate Change and Water Supplies: Options for Sustaining Tank Irrigation Potential in India

K PALANISAMI, RUTH MEINZEN-DICK, MARK GIORDANO

Climate change will affect water supplies in south Asia, where high-intensity floods and droughts are expected in the future. Increasing water storage is a key adaptation strategy, and the experience of irrigation tanks illustrates both the potential and challenges of this adaptation response. Although there are over 2,08,000 tanks in India, irrigating about 2.3 million hectares in 2000-01, the net area irrigated by tanks declined by 29% between 1990-91 and 2000-01 and by 32% between 2001 and 2008. This paper reviews the challenges faced by tank irrigation and examines options for improving their performance – revenue mobilisation through multiple use of tanks, augmenting groundwater resources in the tanks, integrating social forestry and desilting, and tank modernisation.

The Fourth Assessment report of the Inter-Governmental Panel on Climate Change (IPCC 2007a) has confirmed the increasingly strong evidence for the influence of human activity on the global climate. The IPCC has projected that average global temperature of the air above the earth's surface would rise by 1.1°C-6.4°C over the next 100 years depending upon the scenario. Although there is considerable uncertainty in the precipitation projections for the future, it is likely that precipitation may increase in high latitudes and parts of tropics and decrease in some sub-tropical and lower mid-latitude regions. More floods, droughts, decreases in agricultural and aquaculture productivity, displacement of millions of coastal dwellers due to sea level rise and intense tropical cyclones, and the degradation of mangroves and coral reef ecosystems are considered to be some of the likely consequences of climate change (IPCC 2007c). Indeed, heavy precipitation related floods, storm surges, and relatively higher temperatures have led to devastating consequences in recent years.

For south Asia (Indian region), the IPCC has projected a rise in temperature of 0.5°C-1.2°C by 2020, 0.88°C-3.16°C by 2050 and 1.56°C-5.44°C, depending on the scenario of future development (IPCC 2007b). Overall, the temperature increases are likely to be much higher in the winter (rabi) season than in the rainy season (kharif). Precipitation is likely to increase in all time slices in all months, except during December-February when it is likely to decrease. Such global climatic changes will affect agriculture through their direct and indirect effects on crops, soils, livestock and pests.

1 Climate Change and Water Storage

South Asia is considered to be particularly vulnerable to the environmental changes due to its large population, predominance of agriculture and limited resource base. In particular, the irrigation sector will be strongly affected by climate change, as well as by changes in the effectiveness of irrigation methods (Kundzewicz et al 2007). The predicted increased variability of precipitation, which includes longer drought periods, would lead to an increase in irrigation requirements, even if the total precipitation during the growing season remained the same (Eheart and Tornil 1999). Hence water storage as a means to conserve flood waters due to climate change will gain more importance in the future.

Given the options for storage and distribution of the water resources, small and medium reservoirs offer considerable scope to adapt to climate change. During floods, they offer scope to store the excess water, and allow for both irrigation and groundwater

K Palanisami (*k.palanisami@cgiar.org*) is with the International Water Management Institute, ICRISAT; Ruth Meinzen-Dick is with the International Food Policy Research Institute, Washington; and Mark Giordano is with the International Water Management Institute, Colombo.

recharge during times of water shortage. Distributed across the landscape, these reservoirs capture more water, and provide for more local control compared to a few large reservoirs. Hence, there is considerable interest in building such reservoirs as an instrument of adaptation to climate change.

India has an extensive network of existing small and medium reservoirs, called tanks, some dating back to several centuries. The experience of these tanks illustrates both the potential and challenges of distributed water storage as an adaptation response to deal with climate change. In this paper we review key findings from an extensive set of detailed studies on various aspects of irrigation tanks, especially in Tamil Nadu. Following an overview of the extent of irrigation tanks and their declining performance in recent years, we turn to examine the options for improvement of tanks and the accompanying policies and actions needed from the government and farmers. The experience with tanks in Tamil Nadu is instructive not only for peninsular India but also for other sites considering investment in water storage for climate adaptation. It shows that technological interventions alone are not enough; sustainability requires institutional attention, not just for management purposes but also to mobilise the resources required to maintain the water storage.

2 Tank Irrigation Systems in India

Tank irrigation is the use of storage ponds ranging in size from 20 hectares to 1,000 hectares. It is a significant input in agricultural production in large parts of south and south-east Asia. In south India, tank irrigation has a millennial history and many tanks currently in use were constructed centuries ago. Of the 3.2 million acres of tank-irrigated area in India, the three southern states of Andhra Pradesh, Karnataka and Tamil Nadu account for about 60% (Table 1). Together, the tank-irrigated areas of these states produce about 4.5 million tonnes of rice per year, approximately 25% of rice production in these states.

Table 1: Net Area Irrigated under Tanks in India

No States	No of Tanks	% to Total Tanks	1990-91*		2000-01**		% Area Decline in 10 Years
			Area Irrigated (ha)	% to Total Area	Area Irrigated (ha)	% to Total Area	
1 Andhra Pradesh	60,745	29.15	9,69,319	29.88	8,22,306	35.90	15.17
2 Karnataka	20,152	9.67	2,38,560	7.35	1,92,469	8.40	19.32
3 Maharashtra	12,539	6.02	3,10,692	9.58	2,92,155	12.75	5.97
4 Tamil Nadu	39,366	18.89	5,30,406	16.35	3,48,888	15.23	34.22
5 Sub-total for four states	1,32,802	63.73	20,48,977	63.16	16,55,818	72.29	19.19
6 Sub-total for other states	75,579	36.27	11,95,235	36.84	6,34,711	27.71	46.90
7 All India total	2,08,381	100.00	32,44,212	100.00	22,90,529	100.00	29.40

For Tamil Nadu state, the data is from *Tamil Nadu – An Economic Appraisal*.

* Directorate of Economics and Statistics, Ministry of Agriculture, as quoted in World Bank (1998: 128).

** Minor Irrigation Census (2000-01), Ministry of Water Resources, Government of India (2001).

Source: Vaidyanathan (2001).

Data from the Agricultural Census of India for five time points, viz, 1970-71, 1976-77, 1980-81, 1985-86 and 1990-91 indicated that landowned by resource-poor farmers (owning less than two hectares) still account for a major share of tank-irrigated area in India. Marginal (less than 1 ha) and small farmers (1-2 ha) together accounted for about 40% of tank-irrigated area in 1970-71, which further increased to nearly 55% in 1990-91. On the other hand, the share of tank-irrigated area under large

farmers declined from 13.59% to 6.02% during this period. Since the farmers belonging to the marginal and small-size group are mostly poor, they could not afford cost-intensive irrigation sources like groundwater. Hence, tank irrigation continues to play a crucial role for them. This is also true across different states where tank irrigation has considerable presence even today (Narayanamoorthy 2004).

Southern India is noted for its intensity of tanks. Unlike north India, the rivers in the south are mostly seasonal and the plains are not very extensive. Further, the geology is not favourable for groundwater storage. The local topographic variations have been effectively exploited to impound rainfall in tanks which are used to raise irrigated rice crop and simultaneously serve as means of improving groundwater recharge in the command areas. There are about 1,20,000 tanks in the southern region consisting of Andhra Pradesh, Tamil Nadu and Karnataka (Agarwal and Narain 1997).

Among the southern states, Tamil Nadu alone has about 39,366 tanks of varying sizes and types. The total storage capacity of these tanks is about 9,840 million cubic metres (mcm) compared to 6,896 mcm under all the major and medium reservoirs in the state (Government of Tamil Nadu 2003). This indicates that tanks offer more scope for storing the surplus water from floods. Out of this, about 12% are system tanks (which receive supplemental water from major streams or reservoirs in addition to the yield of their own catchment area); and about 88% are non-system/rainfed tanks which depend on the rainfall in their own catchment area and are not connected to major streams/reservoirs.

In ancient days, tanks were considered to be the property of rulers. The farmers paid a portion of the produce to the ruler. Farmers also were in charge of the maintenance of the tanks and supply channels. Zamindars ensured proper maintenance of the tanks and channels, since they reaped the benefits of farming in large areas and also acted as tax collectors to the rulers. However,

when the British introduced the *raiayatwari* system in 1886, tanks with a command area of 40 ha and above were brought under the control of the public works department (PWD) and smaller tanks were under the administrative control of local bodies or vested with the villagers themselves. Since the local bodies did not

have qualified engineers, and the duties of the water users were not clearly defined, the system of the farmers themselves taking up maintenance work – known as *kudimaramath* works slowly declined. Tanks silted up and supply and distribution channels choked. The deterioration of the tank irrigation system has been a subject of considerable discussion, at least since the middle of the 19th century. The report of the Public Works Commission of 1852 stated that there was not much of voluntary community

labour involved in tank maintenance, and it reported that in all districts, labourers were more or less forced to work. In fact, the Madras Compulsory Labour Act of 1858 (or what is known as the Kudimaramath Act) was passed with a view to legalise compulsory labour for certain aspects of maintenance, and also to penalise the non-performance of kudimaramath labour. The Famine Commission of 1878 brought to light quite forcefully the deteriorating conditions of tanks and advocated a systematic policy of maintenance. One of the most important

Table 2: Land Productivity by Source of Irrigation in Tank-Irrigated States

States	Land Productivity (Tonnes/ha)*			% Productivity Higher in Wells over Tanks	% Productivity Higher in Canals over Tanks
	Wells	Canals	Tanks		
Andhra Pradesh	5.7	3.4	2.00	185.00	70.00
Tamil Nadu	6.5	2.6	2.30	182.61	13.04
Karnataka	4.2	3.5	2.30	82.61	52.17

* Data quoted in Thakkar (1999, p 23). Rest of the data calculated by the author.

Table 3: Share of Different Sources of Irrigation in India and Tamil Nadu (in %)

Source	Share of Different Sources of Irrigation in India and Tamil Nadu (in %)						
	1960-61	1970-71	1980-81	1990-91	1999-2000	2005-06*	
India							
Canals	42.05	41.28	39.40	35.63	31.29	29.25	
Tanks	18.5	13.22	8.24	6.84	5.18	4.57	
Wells	29.56	38.22	45.70	51.04	57.81	60.88	
Others	9.89	7.28	6.66	6.49	5.73	5.30	
All	100	100	100	100	100	100	
Tamil Nadu							
Canals	35.80	33.90	32.70	32.40	27.58	27.40	
Tanks	38.00	34.50	32.10	22.38	19.47	19.69	
Wells	24.20	29.80	33.80	44.61	52.88	52.64	
Others	2.00	1.80	1.40	0.61	0.37	0.27	
All	100	100	100	100	100	100	

*For India, this relates to 2001-02.

Source: Tamil Nadu – An Economic Appraisal (various issues).

recommendations of the commission was the creation of tank restoration parties (Palanisami et al 1997). The village-level irrigation institutions such as kudimaramath had also slowly become inactive and their roles insignificant. Government allotment of funds has become insufficient for the operation and maintenance (O&M) of the tanks (Palanisami and Easter 2000). Hence there is an urgent need to sustain the tank management through appropriate interventions.

The share of tank-irrigated area in India has declined from 16.51% in 1952-53 to 5.18% in 1999-2000, whereas the share of groundwater irrigation has increased from 30.17% to 55.36% during this period. The share of tank-irrigated area in net irrigated area (NIA) between 1990-91 and 2000-01 declined by 29.4%; and among the states, the highest decline was observed in Tamil Nadu (34%) and the lowest for Maharashtra (6%) (Table 1). As a consequence of the decline in tank irrigation, the productivity of land under tanks is also observed to be low, compared to other sources of irrigation. Compared to tanks, land productivity per ha is 13% higher under canals and 183% higher under wells (Table 2). This calls for a revival and improvement of tanks for tank irrigation to remain a viable irrigation source.

Among the states, Tamil Nadu has experienced a gradual decline in tank-irrigated area over the years (Table 3). In a 10-year period, the tanks in the state usually get normal supply for three years, deficit supply for five years, and the water supply fails

completely for two years (Table 4). Given the rainfall uncertainties, the tank performance is likely to see a decline over the years. There are above-outlet problems such as poorly maintained structures (bunds, surplus weirs). Catchment is mismanaged and the government has already converted the forest land adjacent to the catchment for human settlement. There is severe encroachment in the tank foreshores. Siltation of the tank bed has reduced the water storage capacity by 20% to 30%. Below the outlet, channels are broken and seldom maintained, resulting in heavy water losses.

The impact of climate change is likely to be higher in rainfed regions, where tanks are often the major source of water storage and groundwater recharge. Hence it is important to address how best tanks could be restored so that they could act as better water storage structures. This paper outlines some of the options that will be useful for implementation by the policymakers.

3 Options for Improvement

There are several suggestions for improving tank irrigation systems, including both technical and management interventions. Broadly speaking, the strategies can work to save water and extend the surface irrigation or increase recharge and conjunctive use of groundwater or both.

3.1 Resource Mobilisation through Multiple Tank Use

The major source of tank O&M expenses is from funds allotted by the government, which have been almost constant in real terms over the years. Each tank requires an O&M expenditure of about Rs 300/ha/year whereas government allotment ranges from Rs 55/ha to 161/ha depending upon the tanks and regions. Hence there is an urgent need to identify alternative methods of mobilising revenue for tank management. This primarily includes the aggregation of revenue from multiple uses of tanks

Table 4: Rainfall and Tank Irrigation Probabilities (Tamil Nadu)

Average Wet-Season Rainfall (mm)	State of Tank Storage	Probability of Occurrence
> 500	Surplus	0.10
450 – 500	Normal	0.20
300 – 450	Deficit	0.50
< 300	Failure	0.20

Based on 46 years rainfall data.

Table 5: Revenue Realisation at Tank Level from Multiple Tank Uses (Tamil Nadu) (Rs per ha)

Tank Type	Irrigation	Fishing	Ducks	Bricks	Social Forestry	Trees	Silt	Total
PU, head	80.38	6.67	0.24	0.47	228.09	2.55	0.00	318.40
PU, tail	51.66	17.00	0.41	0.08	284.01	2.70	0.00	355.85
PU	66.02	11.83	0.32	0.28	256.05	2.62	0.00	337.12
PWD, head	101.04	3.36	0.07	0.21	242.22	0.41	0.00	347.31
PWD, tail	88.21	20.83	1.42	0.10	49.27	1.07	0.00	160.88
PWD	94.05	14.62	0.60	0.14	160.10	0.77	0.00	270.29
Average	88.00	14.87	0.48	0.15	170.85	1.05	0.00	275.40

PU = Panchayat Union tanks.

PWD = Public Works Department tanks.

Source: K Palanisami and Ruth Meinzen-Dick (2001).

fees (Rs 88 per ha) and fisheries (Rs 15 per ha). The total revenue realised in terms of taxes, fee, etc, ranges from Rs 337.12 per ha in panchayat union (PU) tanks to Rs 270.29 per ha in PWD tanks,

with an average realisation from the tanks at Rs 275.40 per ha (Palanisami and Meinen-Dick 2001). This is higher than the average government allotment of Rs 140 per ha for tank o&m. Present practices do not seem to be even exploiting the full potential of tapping all the uses of tanks to generate revenue for tank o&m. Further, the fees generated do not go directly to the tanks, which remain dependent on state government allocations. Hence tanks suffer from a lack of maintenance funds, which is one of the major reasons for the poor condition of the tanks. Currently the state revenue department, social forestry department, mines department, panchayats, and informal organisations in the village community are all involved in collecting revenue from the tank users. It is important to explore the possibilities of revenue collection from multiple uses by a single institution such as local panchayats or water users association.

3.2 Conversion of Tanks into Percolation Ponds

A large number of tanks have become defunct (not used for gravity irrigation). In less tank-intensive districts (where tanks are not the major source of irrigation), about 76% of PU tanks and 64% of PWD tanks have become defunct compared to tank-intensive regions, where the percentage of defunct tanks is less than 3% (Table 6). Out of the defunct tanks, about half are performing as percolation tanks recharging the groundwater (Palanisami 2000).

Even when tanks do not supply surface irrigation, they can still contribute to enhanced water storage by converting them into percolation ponds by deepening the storage area and encouraging farmers to invest in private wells in the command area. To test the economic returns for such conversion, a partial budget was worked out with the aim of comparing the financial gains and losses. Three situations, viz, tanks only, tanks plus wells and wells only (percolation tanks) were compared based on an in-depth study of 15 tanks in south Tamil Nadu. The net income was higher (Rs 49,000/ha) under the percolation tank category compared to other categories (Table 7) (Palanisami and Amarasinghe 2008). As such the PU tanks provide more scope for such conversions, as they have less inter-village variability and the number of farmers covered under such tanks is also comparatively less.

3.3 Canal Lining and Sluice Management

Water loss in the canals is about 30% besides creating inequity in distribution between head and tail farms. Lining the main canals can be undertaken without disturbing the field boundaries.

Tank management strategies such as sluice rotation will also help in saving tank water. Currently the tank sluices are continuously open and the tank water is exhausted within six to eight weeks of tank water release for crop cultivation. To keep the tank water available for a longer period as well as to recharge the wells, the tank sluices can be opened and closed during alternate weeks. Earlier studies (Palanisami and Flinn 1988) indicated that this practice saved tank water by about 20% and extended the tank water supplies to two and a half months instead of the present supply of one and a half months with continuous opening of the sluices.

Sluice management would also increase groundwater recharge. Although non-well owning farmers would have to pay for groundwater purchase from the well owners during the alternate weeks when the sluices are closed, under the present system too, they buy water after the tank supplies are exhausted. Under sluice rotation, the extension of the season and greater groundwater recharge can actually reduce the cost of purchased groundwater. Further, due to sluice rotation, wells can be used more efficiently. Currently they can pump for only two to three hours per day due to poor recharge, particularly during the latter part of the tank season (Palanisami 2000). Sluice rotation can allow up to six hours of pumping per day, which increases the profits for well owners as well as water availability for other farmers.

3.4 Linking Tank Social Forestry and Tank Desilting

Since 1984, social forestry plantations (mainly *acacia nilotica*) occupied the tank water spread area, prohibiting the desilting process by the farmers. The current popular view is that social forestry should be removed from the tank area and complete

Table 6: Defunct or Inactive Tanks across Regions (Tamil Nadu)

Region/Tank Type	Number of Tanks		Mean Command Area (ha)	
	PU	PWD	PU	PWD
<i>I Tank intensive districts</i>				
(a) Total tanks counted	2,064	487	—	—
(b) Functioning tanks	2,039 (98.8)	474 (97.4)	12.67	105.2
(c) Defunct tanks	25(1.21)	13(2.62)	15.81	74.81
<i>II Less-tank-intensive districts</i>				
(a) Total tanks counted	67	90	—	—
(b) Functioning tanks	16 (23.9)	32(35.6)	22.48	79.75
(c) Defunct tanks	51(76.1)	58(64.4)	18.16	99.46

(i) Figures in parentheses represent the percentage of tanks to the total number of tanks in each category.
Source: Palanisami et al (1997).

Table 7: Value of Production in Tanks under Different Typologies (Tamil Nadu)

Typology	Total Income (Rs/ha)	Additional Income (Rs/ha)	Cost of Cultivation (Rs/ha)	Net Income (Rs/ha)	Net Income over Tanks Alone (Rs/ha)
Tank alone	28,343	0	17,589	10,754	0
Tank + well	71,406	43,063	38,719	32,687	21,933
Wells alone (percolation tanks)	1,06,582	78,238	57,505	49,076	38,322

Source: Palanisami and Amarasinghe (2008).

desilting should be undertaken. Also there is increasing pressure from the farmers for removal of plantations as they consume more tank water. A study (Palanisami et al 2006) on the water consumption by trees has shown a linear increase in uptake and utilisation with the age of the trees, with a corresponding increase in the biomass production. But there is no significant loss in tank water compared to tanks without the social forestry plantations, as the tree cover prevented the evaporation of water from the tank, and in the absence of social forestry, *prosopis* trees, which have comparatively less economic value, will occupy the tank water spread area. The efficiency in utilisation of water by the trees also improved: younger trees utilise more water, but yield little biomass (131.16 kg/ha/cm) because more water is spent maintaining the plants and fresh growth rather than developing building blocks. It was noted that 25-year-old trees registered a maximum water use efficiency of 150.93 kg/ha/cm due to more photosynthesis and

conservation of biomass. While analysing the economics of water consumption and biomass value, the cost of water consumed by trees increased from Rs 825/ha/year for five-year-old trees to 6,099/ha/year for 25-year-old trees, with corresponding increase in the value of biomass from Rs 13,603/ha to Rs 1,16,639/ha (Palanisami et al 2006).

Siltation is a major problem affecting tank storage. Silt is impounded in tanks due to sedimentation and the storage

about Rs 45,27,267 whereas the value of groundwater will be only Rs 43,44,587 when the tank supplies are stable (7,733 ha cm). Since the groundwater supplies stabilise the crop production during the tank supply fluctuations, the difference between the two is referred to as stabilisation value of groundwater (Rs 1,82,680) (Palanisami et al 2008b). Since the stabilisation value is higher, it is always useful to increase the number of wells in the command area for conjunctive use with the

Table 8: Economics of Social Forestry and Desilting of Tanks (Tamil Nadu)

No	Social Forestry	Amount (Rs)	Desilting	Amount (Rs)
1	Cost of seedlings @ Rs 2/seedlings for 1,100 nos	2,200	Desilting cost @ Rs 33/m ³ for 77,000m ³	25,41,000
2	Digging of pits (@ Rs 2/pit)	2,200		
3	Watering and maintenance (@ Rs 3/tree for five years)	16,500		
4	Cutting expenses @ Rs 10/tree	11,000		
5	Total cost	31,900	Total cost	25,41,000
6	Income from tree (fuel wood)	18,14,000	Value of silt as manure (25% of 77,000m ³ @ Rs 10/m ³)	7,70,000
7	Fodder value @ Rs 10/tree	11,000	Additional water storage and irrigation benefits (@ Rs 5,000//ha for 20 ha)	1,00,000
8	Total benefit	19,26,000	Total benefit	8,70,000
9	Net benefit	18,94,100	Net benefit	16,71,000
10	Net income from both	2,23,100		
11	Rate of return	8.67%		

Source: Palanisami et al (2006).

capacity of all the tanks has been reduced by half or more. Tank desilting is also viable due to use of silt as fertiliser besides increased groundwater recharge. The cost of desilting in these tanks could vary from Rs 33/m³ to Rs 76/m³ where about 70% of it is accounted for by the transportation cost. Given the high cost of desilting as well as the problems in disposal of the huge volume of silt, partial desilting is recommended. In this context, combining the desilting and social forestry cycles so that the benefits of both activities could coexist would reinforce the benefits from tanks (Table 8). Even though both social forestry and desilting involve certain costs, the benefits are higher with a rate of return of about 8%. In this way, the storage capacity of the tank could be maintained while at the same time realising the benefits of social forestry in the tank beds.

3.5 Investment in Groundwater Resources

Tanks get full storage only in three out of 10 years; in the remaining years, groundwater supplementation is needed. Currently, only about 15% of farmers have wells for supplementation. As such, groundwater supplementation reduces the variability associated with tank water. In the “below normal tank supply” periods, if tank water is not supplemented with groundwater, either the crop yield will decline drastically or the crop will fail completely (Palanisami et al 2008b). The stabilisation value of groundwater (the economic value of reducing variability in production) helps justify better investment in wells in different tank command areas. Normally, the stabilisation value is expected to be higher than the average value of well water under different tank water supply situations. Cross section data related to the selected tanks irrigating both from tanks and wells in Sivagangai and Madurai districts of Tamil Nadu were used to estimate the stabilisation value of groundwater in the tanks.² The average value of the groundwater when supplementing the inadequate and fluctuating tank water supplies during the crop season is

fluctuating tank water. According to a detailed survey, many tank command areas could increase the number of wells by 25% to provide more widespread access to groundwater in these areas (Palanisami and Amarasinghe 2008).

While increasing the number of wells in the tank command area, it is important to keep the well pumping at an optimum level so that maximum number of farmers can benefit.³ Well owners maximise profits from water sales, when the water level is at about five metres, which corresponds to about five to six hours of pumping per day from the well (Palanisami 2000). Hence, in addition to investment in wells, management of well pumping is also important to manage tank systems.

3.6 Tank Modernisation

Tank modernisation is one of the key strategies being recommended in policy documents. Even though tank modernisation has been undertaken on a small scale through different

Table 9: EEC Tank Modernisation: Performance of EEC vs Non-EEC Tanks (Tamil Nadu)

Parameters	EECTanks	Non-EECTanks
Tank performance (%)	81.72	77.63
Filling pattern (no of times)	1.36	1.28
Water availability (no of days)	56.52	52.20
Siltation (%)	36.2	46.8
Presence of WUO (%)	36.0	28.0
Farmers' participation (%)	40.0	42.0
Presence of Neerkatti (%)	68.0	64.0
Maintenance of tanks (%)	44	36
Farm income (Rs/acre)	6,240	5,975
Water management (%)	12	12
Equal water distribution (%)	40.0	38.0
Employment opportunity (mandays)	40.0	40.0
Cooperation among farmers (%)	44.0	40.0
Encroachment (%)	36.2	44.50
Area covered per well (ha)	9	11

Source: Palanisami et al (2008a).

Table 10: Evaluation of Different Tank Improvement Strategies (Tamil Nadu)

Strategies	Production Ratio	Equity Ratio	B/C Ratio	IRR (%)
Sluice modification	1.0	–	0.5	0
Sluice management	1.1	2.6	10.0	142
Canal lining	1.3	1.6	1.8	24.4
Additional wells	1.3	1.5	1.7	23.5
Rotation management	1.4	1.5	10.8	159
Canal lining + additional wells	1.4	1.0	1.5	23.2
Sluice management + additional wells + canal lining	1.5	1.2	1.7	23.7
Rotation management additional wells + canal lining	1.5	1.2	1.4	32.5

(i) Productivity ratio: It is the ratio of increased production with the modernisation strategies to the production at base level.

(ii) Equity ratio: It is the ratio of net income per ha in the head region to the net income per ha, in the tail region.

(iii) B/C = Benefit cost ratio; IRR = internal rate of return.

(iv) Discount rate=10%, life period is varying from 6 to 15 years for different strategies.

For more details, see Palanisami et al (2008a).

Source: Palanisami et al (2008a).

programmes, a major programme was implemented during 1984-85 to 1994-95, with financial aid from the European Economic Community (EEC). In the first phase (1984-91), 150 non-system tanks with a command area of 100-200 ha were selected for modernisation with a financial outlay of Rs 45 crore. In the period 1989-95, an additional 499 tanks were included at a financial outlay of Rs 50 crore. The approximate cost per hectare was Rs 21,000. The project was expected to save about 20% of water over the present use, thus permitting the expansion of cultivation by about 9,000 ha (Government of Tamil Nadu 1986).

In 2008, a comparison between the modernised and non-modernised tanks showed only marginal improvements in

terms of water availability in the tanks, reduction in encroachment and siltation. The presence of water users association and area irrigated by wells also increased only marginally compared to tanks which were not modernised (Palanisami et al 2008a) (Table 9, p 187).

One problem with the EEC programme was the use of a standard package approach that used the same modernisation strategies for all tanks irrespective of their physical conditions. For greater cost effectiveness, it is important to identify selective modernisation strategies.

To identify optimal investments in tank modernisation, different components and strategies have been examined. These include sluice modification, provision of additional wells, sluice management and sluice rotation. Among these options, sluice modification did not improve system performance (Table 10). Sluice management (closing for two days after heavy rain) could increase total rice production by 14%. The options of canal lining, providing additional wells and sluice rotation increased total rice production by between 30% and 36%. The greatest production increase occurred when management and physical investment strategies were used in combination.

4 Need for Investments in Tank Irrigation

As a result of intense budgetary constraints, the share of irrigation investment in total plan expenditure declined from 22% in the First Plan to 11% in the Sixth Plan and to 7% (5% in real terms) in the Eighth Plan (Gulati et al 1999). Out of the total allocation in the Ninth Plan (1997-2002) of Rs 581.64 billion for

Economic & Political WEEKLY

REVIEW OF WOMEN'S STUDIES

April 24, 2010

Women, Embodiment and Personhood

– *Maithreyi Krishnaraj*

Body, Gender and Sexuality: Politics of Being and Belonging

– *Sabala, Meena Gopal*

Women's Bodies and the Medical Profession

– *B Subha Sri*

Embodied Experiences: Being Female and Disabled

– *Nandini Ghosh*

Sex Trafficking and Sex Work: Definitions, Debates and Dynamics

– A Review of Literature

– *Annie George, U Vindhya, Sawmya Ray*

For copies write to:
Circulation Manager,

Economic and Political Weekly,

320-321, A to Z Industrial Estate, Ganpatrao Kadam Marg, Lower Parel, Mumbai 400 013.

email: circulation@epw.in

the irrigation sector, Rs 458.61 billion (78.85%) was allocated for major and medium (M&M) projects (Government of India 1999). The present cost of development of tank irrigation projects is Rs 98,000 per ha for new projects (around 40 ha command area) and Rs 60,000 per ha for rehabilitation projects compared to Rs 3,32,000 per ha for M&M projects (in 2007 prices). If the hidden costs behind M&M projects are included, these would prove even more costly.

There are compelling reasons for giving much greater attention and resources to small-scale surface irrigation schemes (Vaidyanathan 1999). The reported decline in area under this category of works is a reflection of past neglect. These works have not received much attention under the five-year plans, and investments in this category have been meager in relation to the magnitude of the problem. Substantial investments in system im-

Table 11: Financial Evaluation of Tank Investment Strategies (Tamil Nadu)

Source	B/C Ratio*	IRR (%)
System tanks	1.22	19.8
Medium/large tanks	1.25	20.3
Small tanks	1.27	20.6
Non-system tanks	0.50	5.8
Medium/large tanks	0.52	6.2
Small tanks	0.52	6.4

Source: Palanisami and Rosegrant (1995).
Discount rate = 10%.

provement are necessary for improving the quality of surface irrigation, and this must be given priority over the construction of new systems (ibid). Given the fact that tank irrigation investment is important to cope with the impact of climate change in the future, it is essential to see which tanks should be given greater priority for investment. A land-based model developed for identifying the future investment needs indicated that system tanks will have more opportunities for improvement compared to non-system tanks (Palanisami and Rosegrant 1995) (Table 11), because marginal returns to investment will be much higher in system tanks than non-system tanks (Palanisami 2000).

5 Translating the Options into Policies

5.1 Investment Policies

Tank rehabilitation options that restore the original standards should be given priority. Desilting is an important option, but because tanks do not get full storage in most years, desilting tanks fully will not be economical. Also disposal of the entire desilted material is difficult, as the fertile silt is found only in the top (0.4 metre) layer. Therefore, full-scale desilting may not be warranted. Considering the high cost of desilting (Rs 33-76/m³ of silt), partial desilting that helps to restore original (10%) dead storage could be attempted as part of tank rehabilitation options as this will help increase non-irrigation benefits of tank water particularly in the non-tank-irrigation season. Recharging of wells will also improve. Partial desilting can be done nearer to the lower sluice as well as around the periphery of the tank water spread area.

Most of the tanks are not getting adequate water supply and the chain system of tanks has almost broken. Hence, there is an urgent need to revive the tank-chains through appropriate modernisation strategies for improving the supply channels connecting different tanks. This highlights the need for taking up modernisation works

at chain-level, i.e., by considering the entire hydrological boundary as a single unit rather than viewing individual tanks as separate entities for new investment.

Wherever tanks receive less than 40% storage even in normal rainfall periods, they can be converted into percolation ponds and groundwater development encouraged. In other tanks with 40%-70% storages, crop diversification should be encouraged with adequate market facilities and crop insurance programmes. To start with, the PU tanks could be taken up for such conversion given the existing number of wells and the long-term tank storage details. The interest of the non-well owners should however be protected by providing the necessary supplemental irrigation for non-rice crops in the tank season through community wells. District level data base should be generated for such tank-pond conversion.

Since the stabilisation value of groundwater in tank systems increases the value of well irrigation alone, it is recommended to have an optimum number of wells in the tank command areas. That is, one well per 2 ha in a well-only situation, one well per four ha in a tank-cum-well situation and one well per 10 ha in a pure tank situation. In general, the total number of wells in the tank command area can be increased by 25%. Community wells should be installed in the tank water spread area to provide supplementary irrigation to farmers without their own wells during critical periods.

5.2 Management

Farmers in some tanks with water scarcity have already been diversifying their crops from rice to groundnut, pulses, cotton and other crops. This practice should be extended to tanks whose water storage is 50%-60%. The water required to produce one kilogram of rice ranges from 4,500-5,000 litres compared to 1,500-2,000 litres in the case of non-rice crops such as groundnut. Hence, using 50% tank storage, the entire command area can be covered with non-rice crops. Extension efforts and marketing support to farmers should be strengthened to introduce crop diversification particularly in the wet seasons. Crop demonstration by the department of agriculture should help speed up the process. To complement the above options, tank territory structures should be repaired for effective water control.

Though most of the tanks have informal water users' organisations (WUO), only about 30% of them in PWD tanks and 10% of them in PU tanks are found to be active. Officially registering the existing informal WUO, as is done in the canal systems in the state, would enable the organisations to undertake repair and rehabilitation works under government developmental programmes, thereby bringing more resources for tank management. This will also give scope for the revival of Kudimaramath.

Currently the rain-gauges are available in the block offices only and periodical measurement of rainfall intensity is not followed. Rain-gauge stations should be established at different locations of the tank-chains, to measure rainfall intensity and estimate the exact relationship between tank storage and rainfall.

Adequate attention should be given for development of charcoal-making local units in the tank regions, as this will help cut down the *prosopis* trees in the tank water spread area. Local people should also get adequate employment opportunities within the village.

Since the water spread area is very poorly managed, local people should be encouraged to use the tank water spread area for cultivation of seasonal crops like water melon or vegetables soon after the tank water is exhausted. The water users' organisations should be empowered to implement this option without affecting the normal functioning of the tank systems during the rainy season.

5.3 Legal Policies

Tank management requires active involvement by farmers, but not all can be done by farmers themselves, without government

support. More tanks have become defunct in recent years due to encroachment, siltation, choking of supply channels and pollution from industries. Tanks close to the cities should be protected from environmental pollution and further be made as groundwater recharge structures for domestic purposes. Strict regulations and penalty mechanisms should be imposed on the encroachers of catchment, supply channel, and foreshore area, with panchayats empowered to evict the encroachers as well as to prevent further encroachment even if by the government departments.

Necessary legal support should be given to tank water users associations for the collection of fees from tank multiple uses and utilise it for maintenance of the tanks. Also conversion of tanks into percolation ponds should be given legal backing when farmers in the command areas agree.

NOTES

- 1 Cost of water in tank system reflects the water charges, local loss and local loss surcharge. Accordingly, cost of water varied from Rs 0.10 to 0.12 per cubic metre. The biomass (timber) value varied from Rs 1.00 to 1.20 per kg.
- 2 Using the following equations, the stabilisation value of groundwater was estimated (Palanisami et al 2008):

$$\pi(s) = \int_0^s Ydw - p_s s$$

$$= \int_0^s ae^{-kdw} - p_s s$$

$$= (a/k) (1 - e^{-ks}) - p_s s$$

Similarly,

$$\pi(s + g) = (a/k)(1 - e^{-k(s+g)}) - p_s s - p_g g$$

Where, π = profit (in Rs)

s = surface water quantity in ha cm.

g = groundwater quantity in ha cm.

p_s = price of surface water in Rs/ha cm.

p_g = price of groundwater in Rs/ha cm.

a, k are coefficients estimated from the model.

- 3 Using the fitted inverse demand, and output and average cost (AC) functions, and solving the equations for well yield (WY), Inverse demand function: P_p = 36.47 - 2.77 Q_p** (1.622) (0.27)

Where P= price; p = pumped water.

P_p=price of pumped (well) water; Q_p= quantity of pumped (well) water.

$$\text{Output function: } Q_p = -0.237 + 1.19 WY^{**} \quad (0.784) \quad (1.177)$$

$$\text{Cost function: } AC = 11.001* - 0.491 Q_p^{**} \quad (0.49) \quad (0.063)$$

**, * significant at 1% and 5% level, respectively. Figures in brackets are standard errors; the profit maximising levels of WY and Q_p are 5 metres and 5.59 hours, respectively (Palanisami and Easter 2000).

REFERENCES

Agarwal, A and S Narain (1997): *Dying Wisdom: Rise, Fall and Potential of India's Traditional Water Harvesting Systems*, State of India's Environment, A Citizen's Report, Centre for Science and Environment, New Delhi.

Eheart, J W and D W Tornil (1999): "Low-Flow Frequency Exacerbation by Irrigation Withdrawals in the Agricultural Midwest under various Climate Change Scenarios", *Water Resources Research*, 35, 2237-46.

Government of India (1999): *Ninth Five-Year Plan 1997-2002*, Vols I and II, Planning Commission, New Delhi.

– (2001): *Minor Irrigation Census (2000-01)*, Ministry of Water Resources, New Delhi.

Government of Tamil Nadu (1986): *EEC Tank Modernisation*, unpublished paper, Public Works Department (PWD), Chennai.

– (2003): *Report of the Expert Committee on Development and Management of Water Resources of Tamil Nadu*, Vol 1, Water Resources Organisation, Chennai.

– (2002): "Tamil Nadu – An Economic Appraisal, Evaluation and Applied Research Department", Kuralagam, Chennai.

Gulati, Ashok, R Meinzen-Dick and K V Raju (1999): "From Top Down to Bottoms Up: Institutional Reforms in Indian Canal Irrigation", Institute of Economic Growth, New Delhi, mimeo.

IPCC (2007a): *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Geneva, Switzerland, p 104.

– (2007b): *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Solomon, S, D Qin, M Manning, Z Chen, M Marquis, K B Averyt, M Tignor and H L Miller (ed.), (UK: Cambridge University Press), p 996.

– (2007c): *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M L Parry, O F Canziani, J P Palutikof, P J van der Linden and C E Hanson (ed.) (UK: Cambridge University Press), p 976.

Kundzewicz, Z W, L J Mata, N W Arnell, P Döll, P Kabat, B Jiménez, K A Miller, T Oki, Z Sen and I A Shiklomanov (2007): *Freshwater Resources and Their Management. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M L Parry, O F Canziani, J P Palutikof, P J van der Linden and C E Hanson (ed.) (UK: Cambridge University Press) pp 173-210.

Narayanamoorthy, A (2004): "Tank Irrigation in India: Can the Oasis be Rejuvenated?", unpublished paper, Gokhale Institute of Politics and Economics, Pune.

Palanisami, K, G Velu, K Appavu, D Tamilmani and P Paramasivam (2006): "Sustainable Management of Common Property Resources under

Agro-forestry Situations with Special Reference to Tank Irrigation System in Tamil Nadu", *Research Bulletin*, Water Technology Centre, Tamil Nadu Agricultural University, Coimbatore.

Palanisami, K, M Jegadeesan, Koichi Fujita and Yasuyuki Kono (2008a): "Impacts of Tank Modernisation Programme on Tank Performance in Tamil Nadu State, India", *Kyoto Working Papers on Area Studies No 5 (G-COE Series 3)*, Centre for Southeast Asian Studies, Kyoto University, Kyoto, Japan.

Palanisami, K and Upali Amarasinghe (2008): "Tank Irrigation Management with Focus on Groundwater Management and Conversion of Tanks into Percolation Ponds", *Research Report*, CARDS, Tamil Nadu Agricultural University, Coimbatore.

Palanisami, K, R Balasubramanian and A M Ali (1997): "Present Status and Future Strategies of Tank Irrigation in Tamil Nadu", *Bulletin 97*, Water Technology Centre, Tamil Nadu Agricultural University, Coimbatore.

Palanisami, K and J C Flinn (1988): "Evaluating the Performance of Tank Irrigation Systems", *Agricultural Systems*, 28: 161-77.

Palanisami, K (2000): *Tank Irrigation – Revival for Prosperity* (New Delhi: Asian Publication Services).

Palanisami, K and K W Easter (2000): *Tank Irrigation in the 21st Century – What Next?* (New Delhi: Discovery Publishing House).

Palanisami, K and Mark Rosegrant (1995): "Evaluating Future Priorities for Tamil Nadu" in *Strategic Change in Indian Irrigation* (ed.) (New Delhi: Macmillan India Limited).

Palanisami, K and R Meinzen-Dick (2001): "Tank Performance and Multiple Uses in Tamil Nadu, South India", *Irrigation and Drainage Systems*, 15: 173-95.

Palanisami, K Masahiko Gemma and C R Ranganathan (2008b): "Stabilisation Value of Groundwater in Tank Irrigation Systems", *Indian Journal of Agricultural Economics*, Vol 63, No 1, January-March.

Thakkar, Himanshu (1999): "Assessment of Irrigation in India", paper prepared for Thematic Review IV.2 Assessment of Irrigation Options.

Vaidyanathan, A (1999): *Water Resources Management: Institutions and Irrigation Development in India* (New Delhi: Oxford University Press).

– (2001): *Tanks of South India*, Centre for Science and Environment, New Delhi.

World Bank (1998): *India-Water Resources Management Sector Review: Groundwater Regulation and Management*, World Bank, New Delhi.