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Stabilisation Value of Groundwater in Tank Irrigation Systems

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I

INTRODUCTION

Tank irrigation accounts for more than one-third of total irrigated area in Andhra Pradesh, Karnataka and Tamil Nadu States in India. In Tamil Nadu, alone there are 39,000 tanks of varying sizes and types. Normally one rice crop is grown from September to January months where the average rainfall during this period varies from 300 to 450 mm. Out of the 39200 tanks in the state, 22 per cent are called Public Works Department (PWD) tanks (i.e., which have a command area of more than 40 ha. and are maintained by the irrigation department) and others are called Panchayat Union (PU) tanks (i.e., which have a command area of less than 40 ha. and are managed by the local villages) where the small (*ex-zamin*) tanks are also grouped under this category. Tanks are not only useful for irrigation, but it also enriches the water table through percolation. This function of tank is extremely useful in maintaining the water table to ensure sustained growth of flora and fauna in this region. In recent years, due to poorly maintained structures (bunds, surplus weirs), siltation of tank beds and disintegrated channels and weirs, most of the tanks are in a bad state. The main reason is current allocation of funds to modernise the tanks are very meager. For example, the average operation and maintenance (O & M) budget allotted by the state Government for tanks is about Rs. 164 per hectare compared to the requirement of about Rs. 250 per hectare (Palanisami and Easter, 2000).

Tank water supplies fluctuate randomly from year to year and within a year. Using 40 years rainfall data, it was estimated that in five out of 10 years, tanks will be experiencing deficient supply, in three years the tank will fail and in two years the tank will have full supply (Palanisami *et al.*, 1997). The poor performance of the tanks resulted in heavy dependence on groundwater supplementation. Groundwater stocks, on the other hand, are relatively stable because the wells get the recharge both from tanks and from the irrigated rice fields (Palanisami and Easter, 2000).

Normally the number of supplemental irrigations required by the farmers could not be met as only about 15 per cent of the farmers owned wells in the tanks. Most of

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the farmers in the tanks area are marginal farmers having less than one hectare and it is expensive for them to invest in wells to meet the supplemental water requirements. It is argued that the Government can invest in community wells or encourage the farmers to invest in their private wells so that all the farmers can share the tank and well water. However, this will be possible only when the value attributed to the groundwater supplementation (stabilisation value of groundwater) is attractive. Further, such information will also help to examine the options like tank rehabilitation and groundwater use in the tank systems. The concept of 'stabilisation value of groundwater' was introduced by Tsur (Tsur, 1997). This concept gains importance in tank systems of Tamil Nadu because unless the value of the groundwater supplementation is attractive at the system level, subsequent investment in new wells by the farmers or the Government agencies will be difficult to justify. At the tank level, groundwater supplementation reduces the variability associated with tank water, since in most of the years tank storage is below normal. Regarding the studies concerned, earlier studies (Palanisami *et al.*, 1997; Palanisami and Easter, 2000) had reported the returns to groundwater in tank systems. However, no studies had reported the stabilisation value of groundwater in tank systems except the study by Ranganathan and Palanisami (2004). This paper in fact developed theoretical models to estimate the stabilisation value of groundwater. The main aim of the present paper is, however, to introduce the concept in a way that agricultural economists can understand the concept easily and apply it to field/survey data.

II

STABILISATION VALUE OF GROUNDWATER IN TANKS

Given the erratic tank filling behaviour over the years, groundwater supplementation is thus highly warranted. However, at the individual farm level, it is easy to appreciate the value of ground water through additional increases in rice yield which is also often varying between farms and tanks depending upon the level of ground water supplementation. Unless the value of the groundwater supplementation is attractive at the system level, subsequent investment in new wells by the farmers or the Government agencies will be difficult to justify. Hence it is important to study the value of groundwater at the tank level. As such, groundwater supplementation reduces the variability associated with tank water, since in most of the years tank storage is below normal. In the below normal tank supply periods, if groundwater is not supplemented then crop yield will be drastically reduced or crop will fail completely. The variable reducing value of the groundwater carries an economic value, which is designated as the stabilisation value (or buffer value in a dynamic context) of groundwater. The stabilisation value is large relative to the overall value of groundwater (Ranganathan and Palanisami, 2004).

III

DATA AND METHOD OF ANALYSIS

Time series data on water storages in tanks and well water use are not available for all the tanks. Hence, data related to Srivilliputtur Big Tank in Virudhunagar district of Tamil Nadu state were used to estimate the stabilisation value of groundwater in the tank. One important requirement for the estimation of stabilisation value of groundwater is time series data on the performance of the system. The Srivilliputtur Big Tank is one of the oldest tank irrigation systems in Tamil Nadu for which well documented time series data are available. The data relating to this tank have been used since 1982 in various studies by the author. Hence this tank system was selected as a good representative of the tank systems in Tamil Nadu and the data relating to this tank were purposely used in the present study to introduce the concept of stabilisation value of groundwater.

Regarding the water usage data relating to various crops in the region, data from experimental stations were used due to inadequate field level data for all the years. The average usage of water at experimental and field level situation are more or less the same, as the farmers are using near optimum levels due to water scarcity in the tank.¹ For each crop, various levels of water and corresponding yields were used in the production function analysis. The cost of surface water was calculated based on the prevailing water charges fixed by the Government for different crops in the region. With respect to the cost of groundwater, annualised cost of well was arrived at using the 10 per cent discount rate and 20 years life of the well and using the total hours of pumping, unit cost of groundwater pumped was worked out. Finally the total water use at the tank level was arrived at by summing the water use by different crops by giving due weightage for water losses. Normally under tank systems, as high as 38 per cent is lost as seepage and percolation losses both from the canal and from the fields (Government of Tamil Nadu, 1996).

A quadratic production function was employed to estimate the crop responses to water:

$$Y_i = a + bx_i + cx_i^2$$

where

Y_i =Yield in tonnes or kgs per hectare to crop i ($i=1$ to 5) and

x_i =Water applied in cm per hectare to crop i .

The value of the marginal product (VMP) was calculated for each crop by multiplying the marginal productivity of water by the corresponding output price. The marginal value product and the corresponding water requirement of the crops

were plotted in the histogram. The histograms were arranged in the descending order of the marginal value product. Each cell in the histogram corresponds to a particular crop, its height represents the value of marginal productivity of irrigation water and its width gives the total water applied to irrigate the crop (Figure 1). For developing a smooth curve from the histogram, the following procedure was used. We assumed an exponential demand function of the form $Y = ae^{-kw}$ where Y is the VMP of water for a particular crop, x is the water used for that crop and k is the coefficient estimated from the fitted function. The coordinates of the midpoint of each bar in the histogram were calculated and these points were used to estimate the parameters a and b of the function using standard statistical procedures. Finally, using the resulting demand function, total profit due to irrigation water was calculated by subtracting total cost

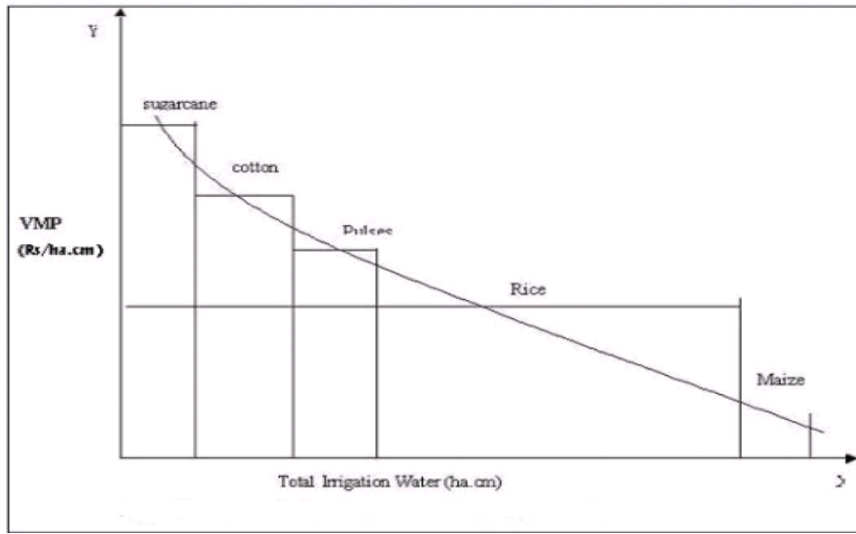


Figure 1. Value of Marginal Productivity of Water and Total Water Use

from the total revenue. The profit with and without ground water were obtained as follows:

$$\begin{aligned} \pi(s) &= \int_0^s Y dw - p_s s \\ &= \int_0^s a e^{-kw} dw - p_s s \\ &= \left(\frac{a}{k} \right) (1 - e^{-ks}) - p_s s \end{aligned}$$

Similarly

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

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.

IV

ESTIMATION OF STABILISATION VALUE OF THE GROUNDWATER

Supply of Surface (Tank) and Well Water

Usually in a 10 year period the tanks get normal supply in 2 years, in 2 years it fails and will have deficit supply during 6 years where groundwater supplementation is highly needed. In the case of the study tank, the tank supply over the years was estimated using the depth of water at different locations and the waterspread area. In those years when the supply was below 30 per cent, then it was considered as tank failure season without any crop cultivation. In the case of groundwater supplies, it was estimated in two stages. In the first stage, sluice-wise number of wells was calculated. In the second stage, details of the wells including water level in different months, horse power (HP) of the engine and the pumping pattern were worked out and converted into standard units (ha.cm) for comparison purposes. The results were further cross checked by summing up the number of supplemental irrigations given by the farmers for different crops in the season.

Estimation of Demand Curve for Water

Using the results of the production function for various crops, the value of marginal products (VMP) was derived for each crop. The VMP and water requirements of the different crops are presented in the Table 1.

TABLE 1. VALUE OF MARGINAL PRODUCT (VMP) AND TOTAL WATER USED FOR DIFFERENT CROPS

Crops (1)	VMP (Rs.) (2)	Total water used (ha.cm) (3)
Sugarcane	483	1080
Cotton	300	4785
Pulses	200	10742
Rice	188	40078
Maize	67	67102

Note: Total water used was arrived in a cumulative manner taking the mid-point values in the histogram as explained in the text.

This value of the marginal product of each crop and its total water requirement were plotted in the histogram (Figure 1). By arranging the crops in the descending order of the value of marginal value of the irrigation water, an approximate of the value of marginal productivity curve for irrigation water was obtained. Then using this data, an exponential form of the demand curve for water was derived (Figure 2).

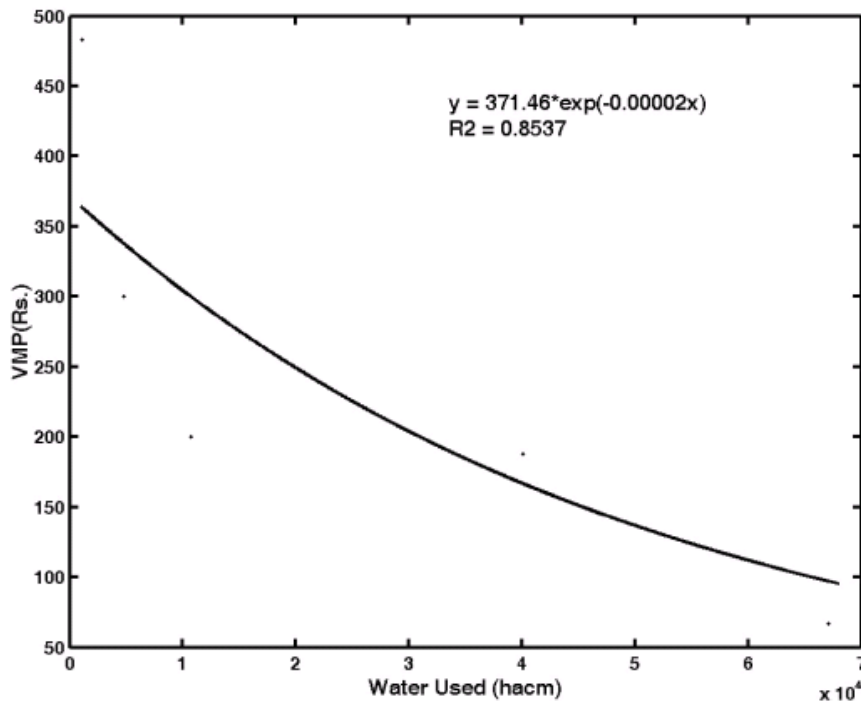


Figure 2. Demand Curve for Water

For each year the values of groundwater and surface water were calculated by the above method. Let S_t $t = 1, 2, 3, \dots, 15$ denote the surface water realisation during 15 years. Let g_t be the groundwater demand associated with S_t and $\pi(S_t + g_t)$ be the corresponding profit. The value of the groundwater when surface water supply was S_t equals $\pi(S_t + g_t) - \pi(S_t)$. The average was calculated by the following formula (Tsur, 1997).

$$(1/15) \sum_{t=1}^{t=15} [\pi(s_t + g_t) - \pi(s_t)]$$

The profit with groundwater minus the profit without groundwater gives the value of groundwater had surface water been stable at the mean level. The difference

between the groundwater value and the groundwater value at mean gives the stabilisation value. The results are given in Table 2.

TABLE 2. PROFIT AND STABILIZATION VALUE OF GROUNDWATER

Year (1)	Surface water (S) (ha.cm) (2)	Groundwater (G) (ha.cm) (3)	Profit (S) (Rs.) (4)	Profit (S+G) (Rs.) (5)	Profit [(S+G)-S] (Rs.) (6)
1986	73451	0	14150036	14150036	0
1987	70561	69	13901496	13907609	6113
1988	45611	25019	11021362	13900623	2879261
1989	40665	29965	10255761	13899238	3643477
1990	71100	349	13948993	13979355	30362
1991	47889	22741	11348990	13901261	2552271
1992	61677	9953	13038889	13992377	953488
1993	23876	46754	7003592	13894537	6890945
1994	63489	7141	13227719	13905629	677910
1995	23145	47485	6835415	13894333	7058918
1996	67453	3177	13617347	13906739	289392
1997	55672	14958	12360664	13903440	1542776
1998	64356	6274	13315651	13905872	590221
1999	65300	5330	13409640	13906136	496496
2000	62349	8281	13109707	13905310	795603
Average	55773	15166	12036351	13930166	1893815
Profit at average S	55773	14857	12372769	13903469	1530700
Stabilisation value of groundwater (Rs.)					363116
Proportion of stabilisation value to total value of groundwater (per cent)					19

The average value of the groundwater equals to Rs. 1893815. The profit assuming that the surface water supply was stable at mean level (14857 ha.cm) equals to Rs. 1530700, the difference between these two rows is Rs. 363116 which is the stabilisation value of the groundwater. This was the value of groundwater due to its role in stabilising the supply of irrigation water (disregarding its role in increasing average supply of irrigation water). The stabilisation value of groundwater accounted for 19 per cent of the total value of groundwater assuming that surface water supplies were stable at the mean would bias assessments of groundwater benefits downward by 19 per cent.

V

TANK REHABILITATION AND STABILISATION VALUE OF GROUNDWATER

An earlier study by Palanisami and Flinn (1988 and 1989) had indicated that several tank improvement options such as channel lining, sluice management, sluice rotation and providing additional wells could improve the tank performance through increased rice production. If these options are incorporated in tank improvement, then there will be about 20 per cent saving in tank water and this means about 20 per cent less demand for groundwater. The stabilisation value of groundwater with 20 per cent saving in tank water will be Rs. 1468194. Due to such saving in tank water, there will

be a reduction in demand for groundwater by 11154 ha.cm (about 75 per cent). An interesting observation from the analysis is that when the quantity of groundwater used is decreasing, the stabilisation value of groundwater is increasing indicating that to get more benefits from groundwater, it is important that system management should be integrated. This is because, in tank systems, the groundwater is used when the tank water is fully exhausted, i.e., groundwater is normally used during the last one month of the crop season. In such a situation, the stabilisation value, in fact, captures the scarcity value of (ground) water. When the tank system is facing water shortages at different levels, the scarcity value of groundwater increases especially when the groundwater is used in the last phase of the crop production. Hence the returns due to foregone benefits will be more at the end of the crop season, where the crop will be in full reproductive stage and whatever groundwater applied will be captured in the stabilised crop yield. Hence in a strict sense, return per unit of groundwater will be high even though the quantity of groundwater used is less.

VI

CONCLUSION AND RECOMMENDATIONS

Given the results of the study, the following policy recommendations are made:

1. *Physical Investment in Wells*: Most of the tanks in Tamil Nadu are in a state of disrepair. Tank water is sufficient for only about 2 months and rice crop normally suffers water shortage and yield reduction upto 1-2 tonnes/ha. Hence given the importance of stabilisation value of groundwater in the tank systems as indicated in this study, it is warranted that supplemental irrigation through groundwater should be provided to stabilise the crop yield. Normally, to provide the needed supplementary irrigation, one well will be required for every 4 hectares of rice crop (threshold level) and currently less than 1 well is accounted for every 10 hectares. Hence, adequate number of wells should be encouraged through government programmes by providing incentives in terms of low interest loans as well as providing electricity connections to the new wells. However, it is cautioned that the number of wells need not exceed the threshold level, as in several cases it was noticed that more wells had discouraged tank management (Palanisami *et al.*, 1997).

2. *Management of Tanks*: Even though well investment is attractive, most of the farmers could not invest in wells as 75 per cent of the tank farmers are marginal and small farmers. Therefore, increasing the availability of tank water from the current level of 2 months to 3 months through sluice management strategies appears an attractive option and with lesser investment in wells this could be achieved (Palanisami and Flinn, 1988). The stabilisation value of groundwater will also increase when tank water is used at higher levels thus minimising the groundwater use. This also will have positive implications for sustainability of tanks, since more

number of wells in the tanks in future may result in poor tank performance. Hence, improving the tank management will enhance tank supplies which in turn will reduce the demand for more number of wells in the tank command area. Hence efforts should be made to improve the system efficiencies through tank modernisation strategies involving the water users organisations/associations.

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NOTE

1. For example, in the case of rice, the experiment station water use was 120 ha.cm and the farmers' level of water use measured in selected locations in the tank command area was 128 ha.cm. Regarding the crop yields, the experiment station yields were higher by 27 per cent and the farm level yield was correspondingly adjusted.

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