Optimal Conjunctive Water Use planning in Tank Irrigation Command Areas under Semi-arid Hydrological Settings in Northern Karnataka

U. Satishkumar[1*], P. Balakrishnan[2] and K. Ramaswamy[3]

[1]Assoc. Professor and [2]Dean (Agril Engg), College of Agril Engg, University of Agricultural Sciences, Raichur [3]Professor, Dept of Soil and Water Conservation Engg, Tamil Nadu Agricultural University, Coimbatore,

Abstract

An optimization model has been formulated to maximize the net benefit from a cascade of tank system with conjunctive use of surface water from the tank and ground water from wells under semi-arid hydrological setting in northern Karnataka tank in the tank area. The paddy being traditional and priority crop of the tank command area farmers, its optimal water allocation plans have been proposed for paddy along with alternative light irrigated groundnut and sunflower crops. The cropping pattern was derived commensurating with the tank inflow quantity at 10 per cent, 45 per cent, 70 per cent and 90 per cent probability levels in all the four tanks and groundwater that could be pumped from the existing wells to the limit of sustainable draw down (2.18 m and 3.06 m). The minimum water productivity of Rs. 1.34 m^{-3} would be assured in the command areas of all the tanks of the cascade system whenever they receive inflows recurrently beyond their capacities (at 10-year or higher return periods) and paddy crop would be cultivated alone. The maximum productivity that could be achieved at very low inflows (at 1 to 1.33 year return period) was in the range of Rs. 3.77 m^{-3} (Gunjalli tank) to Rs. 4.61 m^{-3} (Devanpalli tank), provided light irrigated crops namely, sunflower and groundnut crops were practiced.

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Keywords : optimization model, tank, return periods, cascade tank system, hydrological setting

Introduction

Over the last decade, there has been decline in irrigated area and its productivity, shift in cropping pattern, and decrease in value of production in the tank-based agricultural system of Karnataka. Most of the cascades are formulated by series of tanks organised within the meso-catchment of the landscape and constituting a sub-watershed within the watershed boundary. The runoff flowing out from one tank in a cascade is captured in the subsequent tank at the downstream end. Not many studies were undertaken on the existing status of interdependency between catchment–waterspread-command areas of the cascade systems including irrigation return flows to enhance the water production efficiency without adverse impacts on tank eco-system and social values. In Karnataka, about 1.55 M ha and 0.78 M ha of crop areas are under irrigation by surface and groundwater sources respectively whereas more than 36,000 tanks of varied sizes that spread over in 29 districts have created irrigation potential of about 0.685 M ha (Anonymous. 2007). These tanks have an irrigation command area varied from less than 4 ha (41%), 4-20 ha (42%), 20-40 ha (9%), 40–200 ha (7%) and more than 2,000 ha (1%). The area under tank irrigation has declined to 0.192 M ha (28% of the total potential) due to various management constraints and urbanization (Anonymous. 2007).

In many parts of Karnataka, groundwater exploitation in and around tank irrigation command areas has increased dramatically over the past decade because of increased pressure on irrigated land, subsidised or very low priced power supply and indiscriminate and inequitable use and shrinking tank storage size. Hence, there are more than 40 out of 180 *taluks* in the state are classified as dark (draft levels have reached more than 85% of the annual recharge) and 60 *taluks* as grey with draft at 65 per cent (Anonymous, 2005). The conjunctive use of surface water and groundwater is an important issue that influences to a greater extent on water use efficiency and can be instrumental in reducing conveyance losses and minimising environmental degradation.

Material and Methods

A selected cascade tank system (Devanpalli, Tuntapur, Yergeri and Gunjalli tanks in order of their decent) under semi-arid conditions of Raichur district in northern Karnataka was selected for the study during 2007-2009). The selected cascade with flatter topography (0.34 to 0.72 %) is often susceptible for accelerated erosion due to flash floods coupled with sparse vegetation and unscientific tillage practices. The prevailing semi-arid and sub-tropical climatic conditions of the area the variable inflow pattern at different probability levels (Table.1a to 1d) in all the tanks. The inflow into the each tank was estimated by monitoring daily runoff and subsequent developing rainfall-runoff relation. In the wake of drought situations during many seasons in the past, the farming community has faced the problems in adopting suitable release policy commiserating with variable inflow which has led to the consequences of disparity in water sharing, excessive irrigation, low water use efficiency, mono-cropping, underrated duty and premature crop loss due to water shortage.

The data on monthly water table fluctuations (1973-2007) were collected in the bench mark open wells located in *Tuntapur and Yergeri* villages. To estimate the change in groundwater storage, the water levels were observed though a network of observation wells spread over the area. The change in groundwater storage between the beginning and end of the non-monsoon season indicated the total quantity of water that withdrawn / pumped from groundwater storage (Kumar and Seetapathi, 2002). The change in storage (ΔS) is computed as follows:

$$\Delta S = \Delta h \, A \, S_y$$

where,

Δh = change in water table elevation during the given time period, m

A = area influenced by the well, m^2

S_y = specific yield, per cent

For weathered granite, gneiss and schist with low clay content, S_y is 1.0 per cent as per the recommendation of Groundwater Estimation Committee.

The quantities of annual recharge and annual draft were estimated from the data of recorded levels (h) multiplying with the area of influence equal to the respective command area. Further, annual recharge and draft were compared to decide whether it was excessive recharge or draft. The average recharge or draft depth was calculated and was considered as safe limit of pumping in case of Tuntapur and Yergeri gauging stations

(Fig.1a and 1b). Using the average depth of fluctuation, sustainable replenishing volume that could be withdrawn was estimated. The procedure was extended to of all the tanks for estimating the groundwater replenishment.

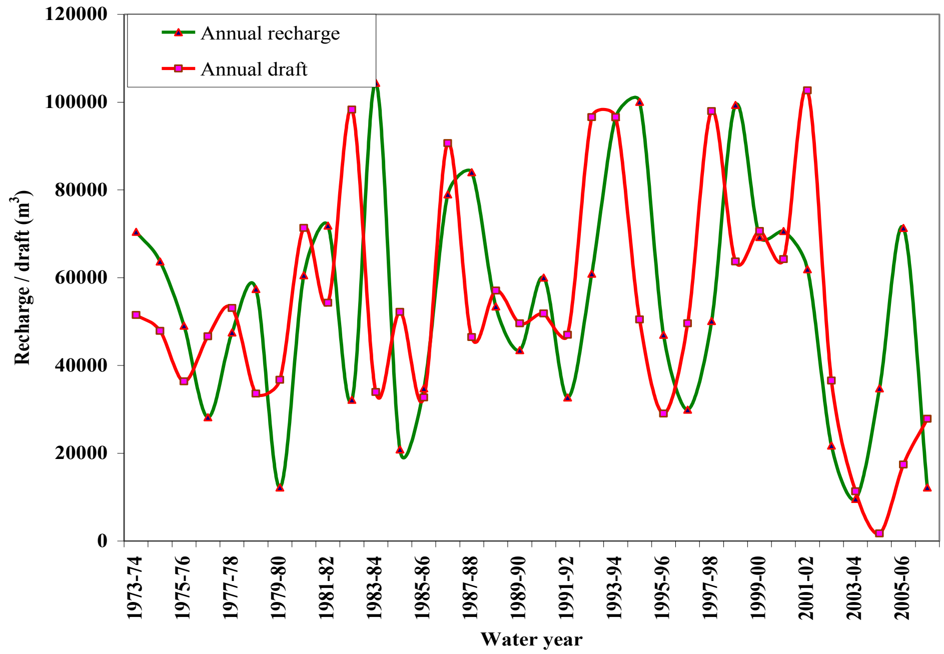

Fig 1a Change in ground water recharge / draft at Tuntapur tank during the period 1973-2007

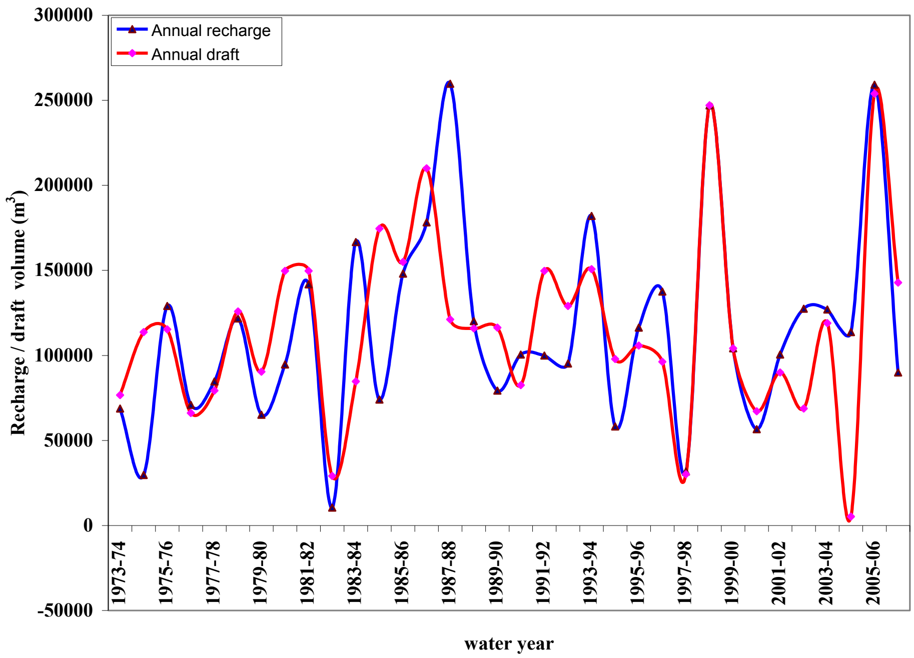

Fig. 1b Change in ground water recharge / draft at Yergeri tank

In order to plan conjunctive use of both tank and ground water sources, linear optimisation model was formulated to optimise the net benefit and to arrive at optimal cropping pattern from the tank command through conjunctive use of surface water from the tank and groundwater potential from the open wells nearby or at fringe areas of the command. The objective function was to optimise the net benefits incurred due to irrigation in the tank command and is given by

Maximise Net benefit (NB)

Subject to

$$\sum_{z=1}^{Z}\sum_{i=1}^{N} B_i A x_{zi} - \sum_{z=1}^{Z}\sum_{i=1}^{N} C_i A x_{zi} - \sum_{z=1}^{Z}\sum_{t=1}^{12} C_{sw} SW_{zt} - \sum_{z=1}^{Z}\sum_{t=1}^{12} C_{gw} GW_{zt}$$

where,

NB = net benefit in rupees, Rs.

B_i = benefit incurred from crop ‘i’, Rs.

C_i = cost of cultivation for crop 'i', Rs.

i = no of crops: i = 1, 2, N

z = sluice number z = 1, 2 and 3

AX_{zi} = area of i^{th} crop under sluice 'z', m^2

t = time period, months

C_{sw} = cost of surface water in Rs. m^{-3}

SW_{zt} = surface water release to sluice z in period't', m^3

C_{gw} = cost of ground water in Rs. m^{-3}

GW_{zt} = ground water pumpage during time period't' in sluice 'z', m^3

The storage at any month should not exceed the total capacity (K_{max}) and not less than dead storage (K_{min}) in all months. In the command areas, other than the paddy, during the lean water inflow years, groundnut and sunflower were cultivated. Hence, only these crops were considered for optimal allocation. The inflow into the tanks at 10, 25, 45, 70 and 90 per cent probability levels were adopted for water allocation (Table 2a to 2d).

$S_t \leq K_{max}$

$S_t \geq K_{min}$

t = 1, 2,…,12 months

where,

S_t = storage in the tank during time period 't'.

Table 1a Estimated storage (M m^3) in Devanpalli tank during different months at different probability levels

P (%	T= 1/P	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total

)														
5	20	0	54,777	87,131	1,89,008	3,44,520	6,28,674	11,30,863	8,68,909	12,55,043	18,66,891	5,80,486	50,984	70,57,285
10	10	0	0	0	90,991	2,51,852	5,26,957	9,64,976	7,34,721	10,70,532	7,36,525	2,46,858	0	46,23,413
25	4	0	0	0	29,285	2,13,476	2,99,896	5,02,584	5,30,768	5,24,312	3,85,886	35,419	0	25,21,627
45	2.2	0	0	0	0	66,419	1,87,261	2,83,926	3,06,492	3,58,230	1,79,941	0	0	13,82,267
75	1.4	0	0	0	0	0	1,11,843	1,10,452	1,74,294	1,97,198	15,769	0	0	6,09,557
90	1.1	0	0	0	0	0	12,510	32,302	46,451	77,013	0	0	0	1,68,276

Table 1b Estimated storage (M m^3) in Tuntapur tank during different months at different probability levels

P (%)	T= 1/P	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
5	20	0	38,381	61,051	1,32,434	2,41,398	4,40,499	7,92,373	6,08,826	8,79,382	13,08,091	4,06,734	35,723	49,44,893
10	10	0	0	0	63,756	1,76,467	3,69,228	6,76,139	5,14,804	7,50,100	5,16,068	1,72,968	0	32,39,529
25	4	0	0	0	20,520	1,49,579	2,10,131	3,52,150	3,71,898	3,67,374	2,70,383	24,817	0	17,66,851
45	2.2	0	0	0	0	46,538	1,31,210	1,98,941	2,14,753	2,51,004	1,26,081	0	0	9,68,526
75	1.4	0	0	0	0	0	78,366	77,392	1,22,124	1,38,173	11,049	0	0	4,27,104
90	1.1	0	0	0	0	0	8,765	22,634	32,548	53,961	0	0	0	1,17,907

Table 1c Estimated storage (M m^3) in Yergeri tank during different months at different probability levels

P (%)	T= 1/P	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
5	20	0	48,171	76,623	1,66,,213	3,02,970	5,52,854	9,94,478	7,64,116	11,03,681	16,41,738	5,10,477	44,835	62,06,155
10	10	0	0	0	80,017	2,21,478	4,63,405	8,48,597	6,46,111	9,41,423	6,47,698	2,17,086	0	40,65,815
25	4	0	0	0	25,753	1,87,731	2,63,728	4,41,971	4,66,756	4,61,078	3,39,347	31,147	0	22,17,511
45	2.2	0	0	0	0	58,408	1,64,677	2,49,683	2,69,528	3,15,026	1,58,239	0	0	12,15,562
75	1.4	0	0	0	0	0	98,355	97,132	1,53,274	1,73,415	13,867	0	0	5,36,042
90	1.1	0	0	0	0	0	11,001	28,407	40,849	67,725	0	0	0	1,47,981

Table 1d Estimated storage (M m^3) in Gunjalli tank during different months at different probability levels

P (%)	P (%)	T=1/P	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
5	20	0	14,635	23,279	50,497	92,045	1,67,962	3,02,132	2,32,146	3,35,309	4,98,776	1,55,088	13,621	18,85,489
10	10	0	0	0	24,310	67,287	1,40,787	2,57,812	1,96,295	2,86,013	1,96,777	65,953	0	12,35,233
25	4	0	0	0	7,824	57,034	80,123	1,34,275	1,41,805	1,40,080	1,03,097	9,463	0	6,73,700
45	2.2	0	0	0	0	17,745	50,030	75,856	81,885	95,708	48,075	0	0	3,69,299
75	1.4	0	0	0	0	0	29,881	29,509	46,566	52,685	4,213	0	0	1,62,854
90	1.	0	0	0	0	0	3,342	8,630	12,41	20,57	0	0	0	44,958

	1								0	6				

The total groundwater pumpage from the wells under each sluice in each month should not exceed the safe yield of the aquifer. The annual quantity of groundwater pumped was estimated based on the safe draft in each tank command area. These constrains are mathematically expressed as follows.

$$GW_{zt} \leq Sy_z \qquad t = 1, 2, 3, \ldots.., 12$$

where,

Sy_z = safe yield of aquifer under sluice 'z', m^3

The quantity of irrigation water required for each crop in each month should be met with either from the surface water in the tank or from the groundwater in the aquifer. The net irrigation demand was estimated using the FAO Modified Penman method. The water allocation constraints are given as below:

$$\sum_{i=1}^{N} NIR_{it} Ax_{zi} \geq \eta_s SW_{zt} + \eta_g GW_{zt}$$

$$t=1,2,\ldots 12 \qquad z=1,2\&3$$

where,

NIR_{it} = net irrigation requirement for the crop 'i' during the month 't', mm

η_s = efficiency of the surface water irrigation (80%), per cent

η_g = efficiency of the groundwater irrigation (85%), per cent

The month to month relation of storage in the tank and releases are given by the continuity equation and mathematically represented as

$$S_{t+1} = S_t + I_t - \sum_{z=1}^{Z} SW_{zt} - E_t - O_t$$

$$t=1,2,\ldots,12$$

where,

S_{t+1} = storage in the tank at time t +1, m^3

I_t = monthly inflow into the tank during time 't', m^3

E_t = evaporation in the tank during time 't', m^3 and

O_t = surplus from the tank during time 't' m^3

Generally, the paddy crop is grown in the command area. In the seasons of acute shortages and areas of higher elevation groundnut and sunflower crops used to be taken up in a smaller extent. The input parameters of the liner optimisation model are presented in Table 2. The linear optimisation model was run using computer compatible premier Solver software. The input parameters to the tank are given in Table 2 and 3

Table 2 Input water parameters of the linear optimisation model for water resource allocation

Sl. No	Particulars	Devanpalli	Tuntapur	Yergeri	Gunjalli
1	Maximum storage capacity, K_{max} (m^3)	19,89,181	11,87,799	11,75,294	43,815
2	Maximum storage capacity, K_{min} (m^3)	1,91,690	50,749	47,335	7,941
3	Command area (ha)	129.6	58.03	176.35	24.31
4	Waterspread area (ha)	91.32	83.57	81.99	21.03
5	No of sluices	3	2	3	1
6	Cost of tank water (Rs m^{-3})	0.35	0.35	0.35	0.40
	Cost of groundwater (Rs m^{-3})	1.05	1.10	1.05	1.10

Table 3 Input crop parameters of the linear optimisation model for water resource allocation

Crops	Cost of cultivation (Rs. ha^{-1})	Returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	Gross irrigation demand in *kharif* (mm)	Gross irrigation demand in *rabi* (mm)
Paddy	30,100	16,000	14,100	1,057	1,190

Groundnut	44,000	30,000	14,000	392.5	437
Sunflower	53,000	24,000	29,000	370.5	440
Vegetables	64,000	29,000	35,000	420.0	470

Results and discussion

The average or sustainable pumping depth in case of Tuntapur tank (3.06 m) was also extended to Devanpalli tank as both are located in the upper pediment area and consist of largely sandy loam to sandy clay loam soils. The Yergeri and Gunjalli tanks are part of the pedi-plains and their larger portions of the area consist of sandy clay loam soils. Hence, the pumping depth of Gunjalli tank command area was also considered as 2.18 m as in the case of Yergri tank system. The sustainable pumping volumes of all four tanks were estimated as product of sustainable pumping depth and respective command area are shown in (Table 4). It was observed that the available groundwater potential could be augmented with tank water for small scale irrigation. The granite aquifers possess very low specific yield and abstractions would quickly lower water levels almost to bedrock and recouping of watertable takes about 2-3 days. These results were in agreement with that of other studies conducted in Sri Lanka (Dharmasena and Goodwill, 1999).

Table 4 Computed groundwater potential of constituent tanks

Constituent tank	Recharge depth (m)		Draft depth (m)		Average fluctuation (m)	Annual potential pumping volume (m^3)
	Maximum	Minimum	Maximum	Minimum		
Devanpalli	-*	-	-	-	3.06*	38,700
Tuntapur	6	0.55	5.9	0.1	3.06	17,400
Yergeri	4.91	0.2	4.8	0.1	2.18	38,720
Gunjalli	*	-	-	-	2.18**	4,380

*Attributes transferred from Tuntapur tank **Attributes transferred from Yergeri tank

The linear optimisation model that was used to allocate the available tank storage augmented with groundwater potential (2.3-year return period level), distributed the command area among three crops namely, paddy, groundnut and sunflower based on their water requirement, cost of cultivation and net profit accrued per ha when subjected to constraints of water availability (both tank and ground water at four probability levels).

The Devanpalli tank having 129 ha of command area could possibly be irrigated with paddy crop completely in both the seasons during the years of inflow expected at 10-year return period (Table 5a). In these situations, a gross demand of 27,09,000 m^3 (1.35 times the existing capacity) could be utilised out of overwhelming inflow (46,23,413 m^3) to raise 129 ha of paddy in each season. At average probability level, (2.3-year return period) with total inflow of 13,82,267 m^3, it would be possible to cultivate 88 ha during *kharif* season but only 14 ha in *rabi* season respectively as sufficient inflow (84,40,97 m^3)would be received by the end of August month. Hence, an additional 45 ha of groundnut could possibly be brought under cultivation at relatively higher elevated area with additional inflow of 5,38,170 m^3 during the north-east monsoon and pumping a groundwater volume of 38,700 m^3. The higher net profit per unit volume of water could be achieved about Rs. 2.01 m^{-3} even with less storage, as against the profit of Rs. 1.34 m^{-3} with the maximum storage possible. This is would be possible only by adopting semi-dry crops rather than paddy only completely. This is also imperative, as there would be reduced inflow relatively from August. At the same time, additional 38,700 m^3 of groundwater could also be augmented by means of open well to support groundnut crop.

The planning of optimistic cropping pattern with dependable inflow at 1.3-year return period (P=0.7) would be more important for annual agriculture perspective plan. Due to reduced inflow nearly by half (6,09,557 m^3), total area under *kharif* paddy needed to be restricted to 23 ha including low lying area along with 32 ha of sunflower, followed by 16 ha of groundnut in *rabi* season. However, water productivity could be increased to Rs. 3.59 m^{-3} as sunflower would fetch relatively higher net profit by consuming less water. Further, it has the advantage of being short duration and could be taken up even at the fag end of the in *kharif* season depending upon water availability.

In some water years, the above inflow could be reduced to be very less than the dead storage capacity and is kept reserve in support of fisheries farming and for summer usage of the village community and domestic animals. However, with support of groundwater for life saving irrigation, 5 ha groundnut could be raised and in *rabi* season, it would be possible to plan 5 ha sunflower crop. In fact, due to switching over to sunflower and groundnut crops water productivity could be increased from Rs. 3.53 m^{-3} to Rs. 4.59 m^{-3}. But because of market forces and farmers' attitude towards growing paddy (an assured crop), the farmers would seek all possible opportunity to go far paddy and only under inevitable situation of water shortage, paddy would be brought to minimum. Hence, while proposing optimising water allocation plan, above aspects also were kept in mind so as to make the plan more pragmatic and reasonable. The above optimised plans emphasised that the profit made by the farmers using both the tank and well water was significantly higher than that of farmers who used either well water only or tank water only (Sakurai and Palanisami, 2001). In the absence of ground water potential (38,700 m^3), there would be marginal reduction (about 4 to 5 ha) in paddy area in *kharif* season which could change the net profit marginally.

Similar trends were followed in other tanks also. The Tuntapur tank (Table 5b) storage, apart from having registered a command of 58 ha area, it also would served an additional 28 ha of fringe area traditionally, during the years of excessive inflows beyond the capacity (11,87,799 m^3). At 10-year return period inflow conditions, in both the seasons, about 85 ha of paddy could be cultivated consuming 23,97,000 m^3 and gaining a net profit of Rs. 1.35 m^{-3} of tank water. In the years of average conditions (2.3- year return period), paddy area would need to be reduced to 81 ha replacing with 22 ha of groundnut area with assured profit at Rs. 1.73 m^{-3} provided conjunctive plan was implemented. With annual recurring inflow level (P=0.9), crop production would need to be restricted to 16 ha of semi-dry crops that too in *rabi* season after receiving all possible inflows in the month of October. In case of possibility of groundwater ignored (17,400 m^3), at all the return periods except 10-year, there would be marginal changes in cropping pattern. The net profit in all these return periods marginally increased as the pumping cost would be saved.

In case of the Yergeri tank (Table 5c) which commands 176 ha area, with total inflow equal to or exceeding 10-years return period interval , it would be possible to irrigate 176 ha in each season and gain a profit of Rs 1.34 m^{-3} utilising 36,96,000 m^3 of surface water. Under average inflow situation (2.3-year return period), in addition to 109 ha of paddy, 30 ha of groundnut could also be cultivated in *kharif* season along with increasing profit margin of Rs. 1.80 m^{-3}. With the inflow equal to 1.11-year recurrence interval, at low lying land holdings, (8.5 ha) paddy could be practised followed by 12 ha of sunflower in *rabi* season. This could raise the net profit of Rs. 3.50 m^{-3} of water drawn from both the tank and ground waters (38,720 m^3). Even though the clay loam to clay soils support recessional cultivation of sunflower and safflower extensively in *rabi* season, the farmers apprehensions about water sharing centres around shrinking the area of paddy to the tune of water availability rather than banking on semi-dry crops or even vegetables. Only under well command, at fringe areas, the farmers do plan well for cultivating vegetables and fruit crops subjected to availability of power for pumping. In the absence of utilisation of groundwater potential (38,720 m^3), at average to annual return periods, paddy area would be reduced proportionately, in return, there would be marginal increase in water productivity (Rs 1.92 to 3.75 m^{-3})

In case of the Gunjalli tank (Table 5d), 20 ha of command area in each season could be cultivated with total water requirement of 4,22,100 m^3 resulting a profit of Rs. 1.34 m^{-3}.On an average condition with inflow at 2.3-year return period, paddy area in *rabi* season would be restricted to 13 ha but with additional 5 ha of groundnut. This cropping plan would repay the net profit at the rate of Rs. 1.58 m^{-3}. With the inflow equal to or exceeding annual recurrence interval, only 7 ha of groundnut could be produced with a net profit of Rs 3.34 m^{-3}. In the absence of groundwater support (4,380 m^3), the cropping plan would be altered by altering paddy and groundnut area marginally for slight improvement in profit margin (Rs 1.66 to 3.34 per m^3). The existing capacity, if enhanced up to the optimal capacity (81,326 m^3), existing inflow pattern would provide enhancement in storage capacity by nearly 80 per cent with which it could be possible to bring an additional 4 ha of paddy or 8 ha of groundnut under irrigation which are facing water shortage at fringe area of the command.

The overall proposed crop planning in the cascade tank system centres around utilising both the surface and ground water sources in tandem to effect increased net profit per unit water. Whenever, the inflow volume would be equal to the tank's capacity or more, paddy dominates the cropping are and as annual inflow volume would recede, lower reach farmers required to replace the paddy area by semi-dry crops preferably groundnut and sunflower by augmenting groundwater judicially. During the low inflow years, farmers need to wait till the end of September to allow maximum inflow and depending upon the situation, semi-dry crops would be taken up. The Devanpalli tank would expected to overflow once in 4 years whereas Tuntapur and Yergeri tanks would get overflowing runoff in 3-4 years. The Gunjalli tank would gets filled practically almost every year. The minimum water productivity of the cascade would be Rs. 1.34 m^{-3}, whereas maximum productivity could be achieved at very low inflows (nearly dead storage capacities) in the range of Rs. 3.34 m^{-3} in case of Gunjalli and Rs. 4.59 m^{-3} in case of Devanpalli. At average probability levels (P=0.45) or with 2.33-year of return period, the water productivity levels range between Rs. 1.58 m^{-3} (Gunjalli) to Rs. 2.00 m^{-3} (Devanpalli). In the absence of groundwater resources, there would be marginal decrease in paddy area and at the same time marginal increase would be expected in productivity. Thus, the results of the investigation would provide potential opportunities for increasing the water productivity both on-farm and at the system level (Guerra *et al.,* 2002).

Table 5a Predicted command area under conjunctive use of tank and ground water resources (m^3) in Devanpalli tank

P (%)	Predicted inflow (m^3)	Ground water potential (m^3)	Paddy (ha)		Groundnut (ha)		Sunflower (ha)		Net profit (Rs)	Gross demand (m^3)	Ne pro (R m
			Kharif	*rabi*	*Kharif*	*rabi*	*Kharif*	*rabi*			
10	46,23,413	-*	129	129	0	0	0	0	36,37,800	27,09,000	1.3
45	13,82,267	38,700	88	14	45	0	0	0	24,05,700	12,07,500	2.0
70	6,09,557	38,700	23	0	16	0	32	0	16,66,300	4,71,500	3.5
90	1,68,276	38,700	0	0	0	5	5	0	2,52,500	5,50,00	4.5
Tank water alone											
45	13,82,267	--	84	14	45	0	0	0	23,49,300	11,71,500	2.0
70	6,09,557	--	18	0	23	0	32	0	16,76,300	4,64,500	3.6
90	1,68,276	--	0	0	0	0	0	0	0	0	0

* not proposed for augmentation

Table 5b Predicted command area under conjunctive use of tank and ground water resources (m^3) in Tuntapur tank

P (%)	Predicted inflow (m^3)	Ground water potential (m^3)	Paddy (ha)		Groundnut (ha)		Sunflower (ha)		Net profit (Rs)	Gross demand (m^3)	Net profit (Rs m^{-3})
			Kharif	*rabi*	*Kharif*	*rabi*	*Kharif*	*rabi*			
10	32,39,529	-*	85	85	0	0	0	0	23,97,000	17,80,000	1.35
45	9,68,526	17,400	52	29	0	22	0	0	16,15,100	9,37,000	1.73
70	4,27,104	17,400	25	0	0	14	0	18	11,75,500	4,01,000	2.98
90	1,17,908	17,400	0	0	0	8	0	8	4,04,000	88,000	4.59
Tank water alone											
45	9,68,526	--	50	29	0	22	0	0	15,15,700	8,90,000	1.89
70	4,27,104	--	22	0	0	14	0	18	11,33,200	3,74,000	3.00
90	1,17,908	-	0	0	0	7	0	8	3,82,500	88,000	4.60

* not proposed for augmentation

Table 5c Predicted command area under conjunctive use of tank and ground water resources (m^3) in Yergeri tank

P (%)	Predicted inflow (m^3)	Ground water potential (m^3)	Paddy (ha)		Groundnut (ha)		Sunflower (ha)		Net profit (Rs)	Gross demand (m^3)	Net profit (Rs m^{-3})
			Kharif	*rabi*	*Kharif*	*rabi*	*Kharif*	*rabi*			
10	40,65,815	-*	176	176	0	0	0	0	49,63,200	36,96,000	1.34
45	12,15,562	38,720	88	21	30	0	0	0	21,81,900	12,09,000	1.80
70	5,36,043	38,720	21.5	5	0	0	30	21	18,52,650	5,34,000	3.47
90	1,47,982	38,720	8.5	0	0	0	0	12	4,67,850	1,42,500	3.50
Tank water alone											
45	12,15,562	--	78	21	40	0	0		22,55,900	11,74,000	1.92
70	5,36,043	--	13	5	0	0	30	21	18,83,300	4,96,000	3.80
90	1,47,982	-	3	0	0	0	0	14	4,48,300	1,04,000	3.75

* not proposed for augmentation

Table 5d Predicted command area under conjunctive use of tank and ground water resources (m^3) in Gunjalli tank

P (%)	Predicted inflow (m^3)	Ground water potential (m^3)	Paddy (ha)		Groundnut (ha)		Sunflower (ha)		Net profit (Rs)	Gross demand (m^3)	Net profi (Rs m^{-3})
			Kharif	*rabi*	*Kharif*	*rabi*	*Kharif*	*rabi*			
10	12,35,233	-*	20	20	0	0	0	0	5,64,000	4,22,100	1.34
45	3,69,299	4,380	20	13	0	5	0	0	5,72,800	3,63,500	1.58
70	1,62,855	4,380	6	0	0	10	0	9	4,93,100	1,58,500	3.11
90	44,958	4,380	0	0	0	7	0	0	1,50,500	45,120	3.34
Tank water alone											
45	3,69,299	-	18	14	0	5	0	0	5,58,700	3,57,500	1.66
70	1,62,855	--	6	0	0	10	0	8	4,71,600	1,53,000	3.18
90	44,958	-	0	0	0	7	0	0	1,50,500	45,120	3.34

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