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Rainwater Management for Smallholder Irrigation and it's Impact on Crop Yields in Eastern India

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Abstract A tank cum open dug well system suitable for plateau region of eastern India has been developed for providing reliable irrigation to croplands. The system comprises of a series of tanks with open dug wells in the recharge zone of the tank that reharvest back the seepage water. Thus, the rainwater remaining in the tank as well as partial seeped water is used for providing round the year full irrigation. This system was evaluated in field in Keonjhar district of Orissa of eastern India with six tanks and five wells in two drainage lines. The total command area of the system of six tanks and five wells in both drainage lines is 23 ha and the total irrigation potential is 44.5 ha. The total cost of the system is US $19,180 making the cost of irrigation resource creation as US $426 per ha which is much less than about $2,220 per ha for major and medium irrigation projects in the last decade of 20th century. The system increased the rice yields from 1.92 t ha^{-1} to a range of 2.25 to 3.8 t ha^{-1} depending upon the package of practices or the amount of inputs. The farmers went for crops in post-monsoon and summer season and the cropping intensity rose to 112% in the first year, 126% in the second year and 132% in the third year. The internal rate of return from the system was 13.4% at the present level of utilization, which is about 2.4% more than the prime-lending rate of Indian banks, and 3.4% more than the lending rate for agricultural purposes.

Keywords Tank and open dug well system · Water balance · Cropping intensity · Internal rate of return

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1 Introduction

The poverty in developing countries can be eradicated, not just alleviated by enhancing the productivity of the smallholder agriculture. In such a case, the agricultural growth serves as an engine for overall economic growth. This win-win scenario of poverty eradication through agricultural and overall growth has been very successful throughout the history and continues to be valid today. As irrigation is a prime catalyst for accelerated agricultural growth, it provides a strong justification for investing in water resource development for small-scale agriculture. This will increase and stabilize the supply of the agricultural outputs throughout the year (Van Koppen 1999). Smallholder irrigation is generally accepted to include farmers who irrigate areas up to fraction of a hectare to 10 ha of land (Albinson and Perry 2002). In some regions smallholders are only able to irrigate part of their land, and must successfully combine their irrigated farming with rainfed growing and livestock enterprises. In most parts of the world smallholder irrigators are relatively resource-poor, rely heavily on family labour and are weak in bargaining power.

The plateau areas of eastern India, comprising of north western and western Orissa, Chhatisgarh, Jharkhand, and southern district of West Bengal are classified as Agro Ecological Region (AER) No.12 by National Bureau of Soil Survey and Land Use Planning, Nagpur (Sehgal et al. 1992). Agro-ecological region 12 is characterized by hot moist sub-humid type of climate with dry summers and mild winters. The area receives a mean annual rainfall of 1,200–1,600 mm covering more than 80% men PET. The region is habitat of most poor people of India with population below poverty line being more than 40% (as per World Development Indicators, 2007, a person whose income is below $1 per day is considered to be below poverty line). Thus, investment in water resource development could potentially be an effective tool to increase the productivity and poverty alleviation/eradication in this region. Unfortunately, the traditional irrigation systems viz., large dams, canal network and deep tube wells are not feasible due to the topographical, geological and geohydrological reasons and these areas face problem of the recurring agricultural drought, in spite of being bestowed with 1,200–1,600 mm annual rainfall. The climatic water balance, humidity, aridity and moisture indices of the representative locations of this agro eco region shows that water deficit is prevalent from November to May in almost all locations (WTCER 2001). The region is trapped in the vicious circle of low agricultural performance, and poverty, the so-called ‘Low Level Equilibrium Trap’, in view of which this region can aptly be called a ‘Resource Rich Region Inhabited by Resource Poor People’ (Srivastava et al. 2003) (The region is called a resource rich region as it receives a reasonably good amount of rainfall and is rich in mines and minerals) To tackle problem of such regions, smallholder irrigation approach is being adopted. This approach focus on implementation of irrigation schemes as part of a rural development process that is initiated, managed and owned by the irrigators themselves.

Several researchers have designed small systems for irrigation management and water resource development based on runoff recycling (Palmer et al. 1982; Helweg and Sharma 1983; Verma and Sarma 1990). But most of them are for supplementary irrigation and hence their impact on total livelihood scenario is not significant enough to bring them out of vicious circle of poverty. Thus there is need for technology, which enables reliable full irrigation to smallholder agriculture to bring it out of the vicious circle of poverty and transform subsistence agriculture to occupational agriculture. The technologies for such system will be area specific and thus required to be designed to be compatible with the specific socio-economic conditions of the farmers. Bhatnagar et al. (1996), Srivastava (1996, 2001) and Srivastava et al. (2004a) have shown that reliable irrigation system through runoff recycling can be designed in sub-humid high rainfall areas of Bangladesh and India. The technology reported by Srivastava (2001, 2004) was further refined and a micro level water resources development system through rainwater management comprising of tanks and wells suitable for small and marginal farmers was conceptualized at Water Technology Centre for Eastern Region (WTCER), Bhubaneswar, Orissa, India (Srivastava et al. 2003, 2004a, b). In this tank cum well system, the runoff water is collected in the tanks of specific designs. This irrigation water availability facilitates conversion of *unbunded* upland rice to *bunded* transplanted rice inducing more rainwater retention in the field. This retention along with the seepage from the tanks recharge the ground water, which can be harvested back through an open dug well. The system function best when the tanks and wells are constructed in series, hence an in-field evaluation of the system was conducted before recommending it for a wider adoption by the development departments. To achieve this objective, such systems were installed in field under National Agricultural Technology Project (NATP) sub project ‘Rainwater management strategies for drought alleviation’. This article presents the results of this study.

2 Materials and Methods

The rainwater management system was designed on the basis of the design parameters developed by Srivastava (2001) and Srivastava et al. (2004a) which gives tank capacity per ha command area depending upon rate of seepage loss from tank (Command area is the area that can be irrigated by a tank). The simulation model (Srivastava 2001) has also shown that the tanks, paddy fields and catchment area contribute to ground water recharge. This process has been schematically shown in Fig. 1. The expected amount of total recharge varies from 3,000 m^3 to 4,800 m^3 per ha command area with 3–5 ha catchment area i.e., approximately 1,000 m^3 per ha catchment area which is equal to 100 mm (Srivastava 2001).

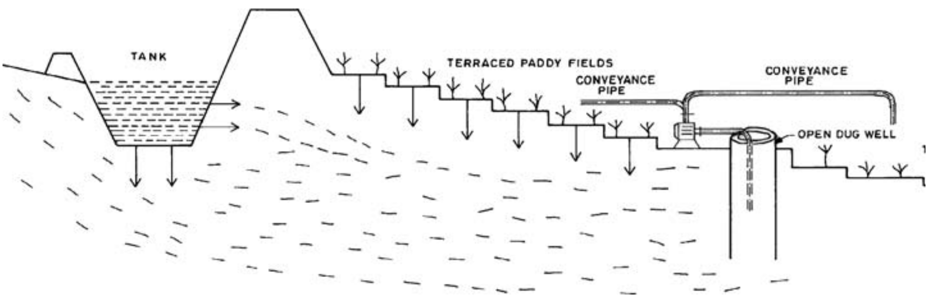


Fig. 1 Schematic diagram of rain water harvesting based tank and well system

2.1 Design of the System

The study area is located in Keonjhar district of Orissa of eastern India. The district has been classified as central tableland zone in sub agro ecological zones of the state (Srivastava et al. 2003). The topography is rolling with overland slope of cultivated areas ranging from 2 to 5% and the croplands are terraced. It was assumed that there would be seepage from catchment, tank and *bunded* paddy fields (the *unbunded* paddy fields get converted into *bunded* paddy fields once the water is available for transplanting). For this study, six tanks and five wells were constructed in two drainage lines. In drainage line-I, there were three tanks and three wells out of which one tank was completely embankment type and was located adjacent to second tank. In drainage line-II, there were three tanks and two open dug wells. The open dug wells were constructed in the downstream side of the tanks to harvest back the water that is lost by seepage from tanks. The water was pumped out from both tanks and wells. Out of six tanks, four were constructed in the community land while two were in private land. All except one well were located in private land. An understanding was reached among users that everybody will have access to water with only one rider that nobody will grow rice in the post-monsoon season. The owner of the land was free to grow horticulture crops in embankment and do pisciculture and duckery in pond and keep the return. The schematic diagrams of this system are shown in Fig. 2. The locations of the tanks and wells were decided on the basis of the hydrological and social acceptability of the sites. The details of the tanks are presented in Table 1. The irrigation potential was estimated on the basis of the assumption that the *rabi* crop (post monsoon season crop, November to March) will be heavy duty crops like potato and other vegetables. With low duty crops, the *rabi* potential will be equal to *kharif* (monsoon season crop, June to October) potential.

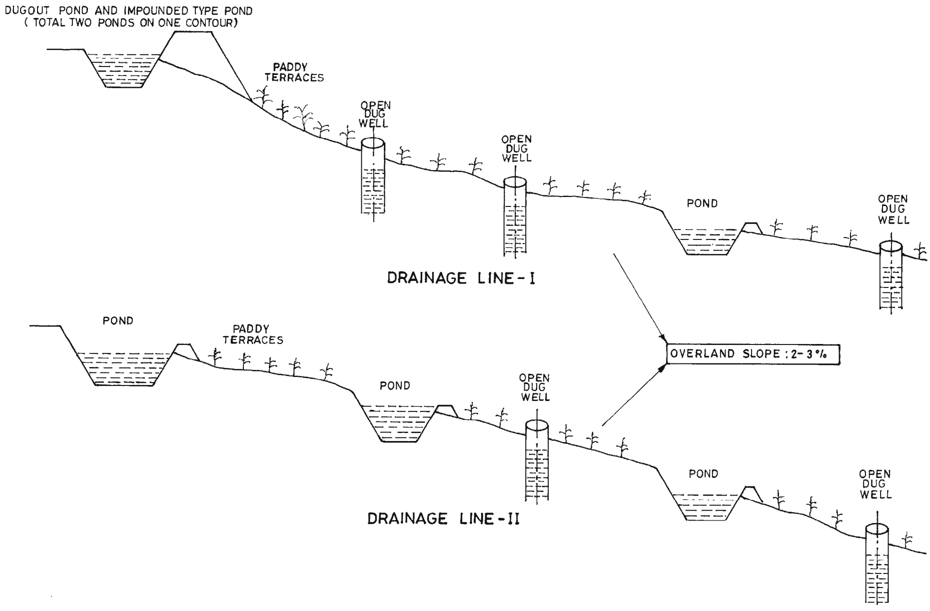


Fig. 2 Schematic diagram of tank cum well system

Table 1 Details of tanks and wells constructed in the study area

Rainwater harvesting structure	Capacity, m^3	Command area, ha	Kharif irrigation potential, ha	Rabi irrigation potential, ha	Summer irrigation potential, ha	Total irrigation potential, ha
Drainage line I						
Tank no. 1 and well no. 1	3,100	3.0	3.0	2.0	1.0	6.0
Tank no. 2 (embankment) and well no. 2	25,000	8.0	8.0	6.0	1.0	15.0
Tank no. 3 and well no. 3	4,400	3.0	3.0	2.0	1.0	6.0
Drainage line II						
Tank no. 1	3,100	1.5	1.5	1.0	–	2.5
Tank no. 2 and well no. 2	4,800	4.0	4.0	3.0	1.0	8.0
Tank no. 3 and well no. 3	4,000	3.5	3.5	2.5	1.0	7.0
Total		23.0	23.0	16.5	5.0	44.5

Total cost of the system = $19,180; cost of irrigation = $426

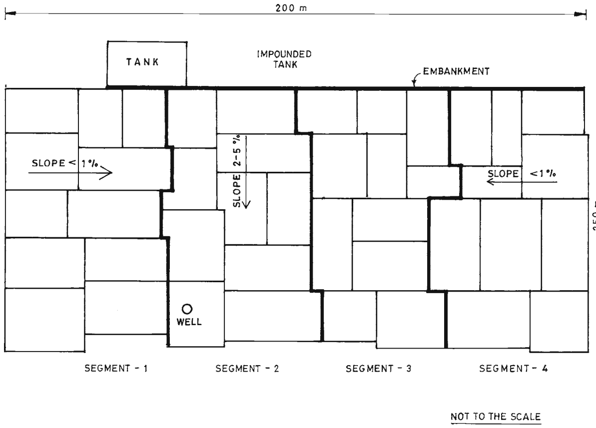
2.2 Hydrological Impact

The water balance of the system was studied by monitoring the water level in the tanks and recording the water pumped by farmers from the tanks and wells for irrigation. The effect of the seepage from the tanks on downstream terraces was measured by monitoring the water level in the fields in the monsoon season both along and across the slope by fixing a measuring scale in the sand filled mug in such a way that level of sand mug and soil surface was the same. The water levels in the wells were also monitored. For evaluation of well yield, pumping tests were carried out in wells during different months to see the effect of the season on the well yield. As these wells are located in hard rock areas without any defined aquifer, the traditional well testing method could not be employed. Therefore the water was pumped from the well with pump being at ground until the water level went below the suction limit. During this period, the water level and discharge were recorded. The amount of water pumped from stored water in well was computed as the area of well multiplied by the change in water level before and after pumping. The difference between total volume of the water pumped and amount of water pumped from stored water was computed as the volume of water pumped from recharged water during that period. After cessation of pumping, periodic recording of the water level in the well was done until it recovered back to its original level. The well with a recharge structure at the upstream side was compared with a well without any recharge structure located in almost similar situation.

2.3 Effect of Water Resource Development on Crop Productivity

In order to evaluate the impact of the rainwater harvesting systems on productivity, production and employment generation, the farmers were advised to adopt the

Fig. 3 Schematic diagram of the plots below the tank



improved cropping pattern and package of practices. In monsoon season, the farmers were advised to go for three types of varieties; short duration, medium duration and long duration. The short duration varieties were planted in upland areas of the command area, the medium duration on medium lands and long duration varieties in fields just below the tanks. The different package of practices adopted by farmers could be grouped as following: (1) farmer's practice (direct sown, no fertilizer, local variety) outside the command area; (2) farmer's practice, inside the command area; (3) local variety, direct sown with recommended fertilizer; inside the command area (4) local variety, transplanted with recommended fertilizer; inside the command area (5) improved package (high yielding varieties, transplanted with recommended dose of fertilizer) inside the command area. Figure 3 shows the distribution of plots in the downstream side of the embankment type pond where the area was divided into four segments and under each segment; treatments 2, 3, 4 and 5 were distributed among the available plots. The effect of the water resource development cum improved package of practices was measured in comparison to the crop performance outside the command where it was local variety with no fertilizer.

In the post monsoon season, the farmers were advised to go for *rabi* crops viz., paddy, potato, tomato, field pea and wheat as second crop and vegetables viz., ladies finger (*Abelmoschus esculentus*), brinjal (*Solanum melongena*), ridge gourd (*Luffa acutangula*), chilie (*Capsicum annum*) and bitter gourd (*Momordica charantia*) as *summer* crop (March to May). Area under post-monsoon season crops was 2.16 ha in the first year. The area increased to 6.15 ha in the second year and 7.37 ha in the third year as the farmers were encouraged by availability of water in tanks and open wells. Vegetable cultivation like pumpkin was taken up along with papaya on the embankment of ponds by the farmers on whose land the pond was constructed. One farmer even put pigeon pea on embankment and got about 20 kg yield. Fish species viz., *Catla catla* (30%), *Labeo rohita* (30%) and *Cirrhinus mrigala* (40%) were stocked at the rate of 10,000/ha in the ponds along with ducks. The yield of the crops and other multiple uses of water, i.e., fishery, ducks raising, horticulture on embankment of the tanks were monitored.

2.4 Economic Impact

The economic analysis was done on the basis of incremental benefits achieved due to water resource development cum package of practices. For this the additional return for *kharif* season crop, i.e., rice was estimated by calculating the additional gross return and additional expenditure for achieving higher yield and utilizing water. For *rabi* crops, the net return from the crop activities were taken as additional returns as there was no crop before development of water resources. In second year, 43.5% farmers utilized full potential in *kharif* season, 20% in *rabi* season and 40% in *summer* season. The internal rate of return was estimated on this actual usage of potential. The internal rate of return (IRR) is the rate at which the Net Present Value (NPV) of a project becomes zero i.e. present value of future cash inflows are equal. Mathematically, IRR is a root of a polynomial of degree '*n*', which can have '*n*' number of solution. On simplifying, it can be estimated as follows.

$$PW_n = \left[INV\,(1-r)^n - B\,(1-x)^n\right](1-r)^n \tag{1}$$

The value of '*r*' is increased till

$$\sum_{n=0}^{N=N-1} PW_n = 0 \tag{2}$$

Where, PW_n = present worth value in *n*th year, INV = initial investment in the project, r = internal rate of return, n = year, N = life of the system, B = annual benefit in first year, and x = expected rate of increment in annual benefits.

The economic efficiency of any irrigation system is function of utilization of irrigation potential. During initial years, the farmers are skeptical about reliability of the system, their risk taking capability is less and therefore the potential utilization is poor. However with time the potential utilization increases. To study the impact of potential utilization on economics of the system, four levels of utilization were envisaged and economic efficiency in terms of benefit cost ratio and IRR were estimated. The four levels of utilization selected were 50, 25, 40; 75, 25, 40; 75, 50, 40 and 100, 50, 80. The level 50, 25, 40 means 50% of irrigation potential utilization in *Kharif*, 25% in *rabi* and 40% in *summer*. The benefit cost ratio and IRR of the scenario presented above were calculated by extrapolating the results of field experiments. When calculating the benefits, the cost of additional labour has not been accounted for, as it is all family labour, which has nil opportunity cost. For calculation of benefit cost ratio, discounted net worth method (Helweg and Sharma 1983) was used for life of 20 years at discount rate of 10%, the prevailing interest rate for medium term loans for farming purpose in India as per information in business newspapers. The following equation was used for estimating net worth and benefit cost ratio.

$$B_P = B\frac{(1+r)^N - 1}{r + (1+r)^N} \tag{3}$$

Where, B_P: discounted net benefit, B: annual net benefit of the system, r: discount rate and N: life of system

$$B - C\ ratio = \frac{B_P}{C\,(1+M)} \tag{4}$$

Where, C: initial investment in the system and M: percent of initial cost required for annual maintenance (A value of 10% of M has been used here based on experience).

For calculation of internal rate of return, two incremental rates of benefit, 5% and 10% were taken, and IRR was estimated for both of them. Incremental rate of benefit is the rate of increase in benefits over 1 year i.e. if the benefit in first year is 1.0, the benefit in next year has been assumed as 1.05 for 5% incremental rate of benefit.

3 Result and Discussion

3.1 Hydrological Impact

The water level data of one pond for years July/2001–March/2002 and July/2002–March/2003 are presented in Fig. 4 which show that high rainfall in year 2001 filled the tank by early July. The water level remained at almost full level for monsoon period and started declining after monsoon. In year 2002, which was an agricultural drought year, rains of until mid June were collected in the tanks. From the 17th June to 25th July, there was a 40 days dry spell that reduced the yield of rainfed crops. However, the water stored in the tanks and in the open dug wells, enabled farmers to complete the transplanting as well as *beushening* of direct sown paddy of the crop located in the command area (Beushening is a practice of paddy cultivation where the direct sown paddy is hoed with standing water. After hoeing the plants are readjusted to proper plant population. This practice kills the weeds and the plant population is made uniform). The rains refilled up the tanks in August, which is evident in Fig. 4. The difference of about 1 m in the maximum depth of water in both years is due to deepening of the pond during summer of 2002. Thus, the system mitigated the effects of the agricultural drought, which was also reflected on the yield levels (presented in later section).

Figure 5 presents the water level of the paddy fields in the command and outside the command area of the structures for the years 2001 and 2002 respectively. It

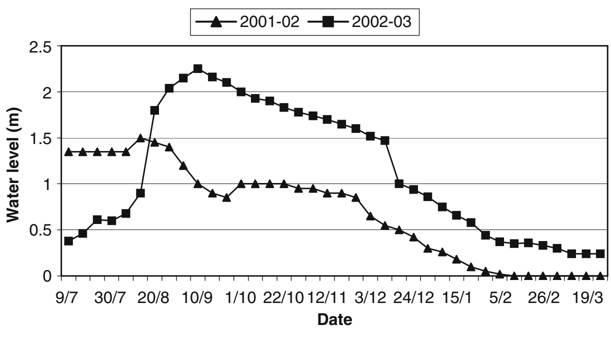
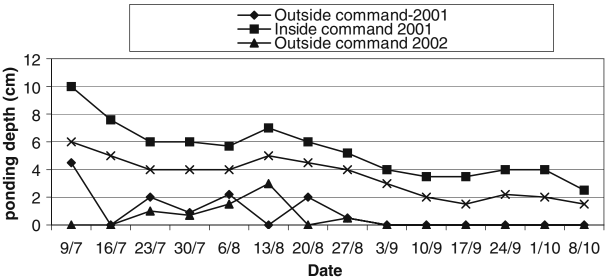


Fig. 4 Comparison of water levels in a pond in years 2001–02 and 2002–03

Fig. 5 Comparison of water level in the fields of command area and outside command area



is evident that the rice fields did not face any moisture stress in both the years even after cessation of monsoon, which was in the last week of September, while the crop outside the command area of the tanks suffered moisture stress in the reproductive phase. Figures 6 and 7 show the paddy crops inside the command area and outside the command area respectively. It was found that the seepage water from the tanks provided the water availability in the fields and the water levels reduced with the distance from the embankment. This trend continued until January. This gave an indication that these areas were more suitable for long duration paddy (July–December) with single crop instead of trying another crop in *rabi* season after harvest of medium duration rice (July–October) in *kharif* season as the fields were not ready for any tillage operation at that time. Thus the system converted the lands which earlier were not able to fully support even 100 days duration rice crop to become suitable for a paddy crop of 160–180 days duration giving yield of about 5 t/ha.

Fig. 6 View of the paddy crop inside the command area in the year 2002

Fig. 7 View of the paddy crops outside the command area

Table 2 gives the water balance of the tanks and wells for one drainage line in 2002–03, which shows that the stored runoff was equal to about 150% of the storage capacity as the losses and uses were replenished by subsequent runoff events. Out of stored runoff, 37.1% was lost as seepage, 4.6% was lost as evaporation and 43.1% was utilized for irrigation. Rest 5.2% remained in the tank for pisciculture, duckery and other domestic uses. Without open dug wells, the ratio of water yield, i.e., water utilized for irrigation and storage capacity is 0.65 which rises to 0.86 with open dug wells as the water lost as seepage is reharvested back through the open dug wells. The ratio is lower as the farmers did not go for full utilization of potential both in *kharif* as well as in *rabi* season. Thus, in short, it can be said that the system mitigated the effect of the drought, changed the hydrology of downstream paddy terraces so as to become suitable for long duration rice, recharged the ground water and provided sufficient water to the crops.

3.2 Groundwater Recharge and Utilization

The pumping data for the well located with a recharge structure (well no. 1) and one without recharge structure (well no. 2) in month of March' 2002 are presented in Tables 3 and 4 respectively, which show that the well having no recharge structure is able to provide just about 20 m^3 of water in one pumping session while the well with recharge structure provides about 96 m^3 of water in 2.5 h after which the water level went below suction limit. Thus the well without recharge structure cannot provide sufficient water required for irrigation. 80% of the 96 m^3 water pumped, came from stored water and 20% came from recharged water. Since in open dug wells, a gradient is created between water level in well and water level in aquifer after pumping, the

Table 2 Water balance of tank and well system in drainage line II (2002–03)

Tank no.	Tank capacity, m^3	Catchment area, ha	Runoff received, m^3	Irrigation water pumped, m^3		Seepage loss, m^3	Evaporation loss, m^3	Water pumped from well, m^3	
				Kharif	Rabi			Kharif	Rabi
1	3,100	6	5,079	340	1,774	2,316	677	No well	
2	4,680	10	5,722	675	1,468	2,257	1,022	352	285
3	4,000	10	6,867	1,026	2,340	1,987	874	504	1,450
Total	11,780		17,668	2,041	5,582	6,560	2,573	856	1,635
			17,668	7,623 (43.1%)		6,560 (37.1%)	2,573 (14.56%)	2,491 (14.1%)	

Total water utilized for irrigation = 10,114 (57.24%); water yield/tank capacity ratio = 0.86

Table 3 Pumping data of well with recharge structure at the upstream side

Cumulative time of pumping, min	Time between two readings, h	Amount of water pumped, m^3	Amount of water pumped from stored water in well, m^3	Amount of water pumped from recharged water, m^3	Recharge rate, m^3/h
0					
65	1.08	44.85	35.93	8.92	8.26
110	0.75	28.35	22.67	5.68	7.57
150	0.67	22.8	18.18	4.62	6.89
Total	2.50	96.00	76.78 (80%)	19.22 (20%)	7.68

water moves from aquifer to well and this continues till both are equal. The rate of water flow from aquifer to well for a particular gradient will be independent of the size of well but the total amount of flow will be a function of size of well because a larger well will require more water to bring the gradient between both water levels to zero. This indicates the need of a larger diameter well, i.e., about 6 m diameter as a minimum amount of water is required to make irrigation practical. A small diameter well will not serve the purpose of irrigation.

Figures 8 and 9 present the recovery process of two wells once the pumping ended. The well located in the recharge zone of the pond recovered 50% of the water pumped within 25 h. The recharge rate was initially fast but declined with time and then stabilized. The condition was totally different in well without recharge structure, which recovered slowly. Hence, once pumped out, these wells recover after a longer period. The time in which 50% of the pumped water is recovered as well as the constant rate of recharge during recovery varied in different months as evident from Fig. 10. It is on expected lines as the time was least in monsoon months and then increased. Similarly the recharge rate was higher during monsoon months and reduced with time. Table 5 presents the summary of the pumping tests of these two wells. Results indicate that an open dug well can function as irrigation source only if it is supported by a recharge structure upstream (see Figs. 8 and 9 and Table 4).

Hydrological and hydraulic study of the system indicates that the tank cum well system is able to provide sufficient water with a quite fair degree of reliability for irrigating or providing irrigation the *kharif*, *rabi* and *summer* crops.

3.3 Impact on Crop Productivity and Cropping Intensity

3.3.1 Kharif Crop

Table 6 presents the rice yields under different package of practices for years 2001, 2002 and 2003 respectively, which indicate that in drought year 2002, mere direct

Table 4 Pumping data of well away from the drainage line with no recharge structure upstream

Cumulative time of pumping, min	Time between two readings, h	Amount of water pumped, m^3	Amount of water pumped from stored water in well, m^3	Amount of water pumped from recharged water, m^3	Recharge rate, m^3/h
0					
11	0.183	6.26	6.16	0.1	0.55
21	0.166	5.08	4.88	0.195	0.18
36	0.25	7.65	7.01	0.64	2.57
Total	0.6	18.99	18.05 (95.07%)	0.937 (4.93%)	1.43

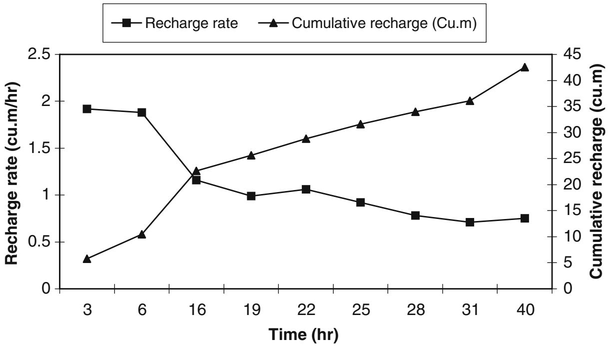


Fig. 8 Recharge recuperation curve of well with recharge structure

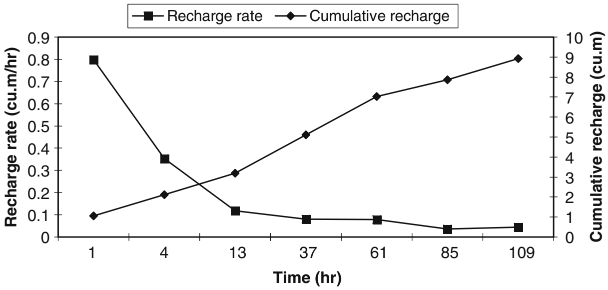


Fig. 9 Recharge recuperation curve of well without recharge structure

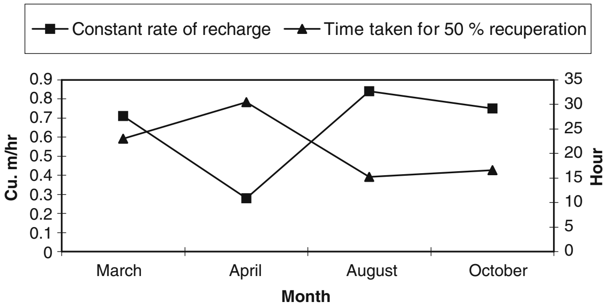


Fig. 10 Time for 50% recoupment and the constant rate of recharge for recoupment

Table 5 Comparison of two wells with and without upstream recharge structure in March 2002

Item	Well without recharge structure	Well with recharge structure
Water available in one pumping session	19 m^3	96 m^3
Time of pumping	36 min	150 min
50% recovery period	109 h	25 h
Average of recharge in recuperation	0.215 $m^3\ h^{-1}$	1.15 $m^3\ h^{-1}$
Constant rate of recharge in recuperation	0.05 $m^3\ h^{-1}$	0.78 $m^3\ h^{-1}$

Table 6 Impact of irrigation and other improved practices on rice yield

Farming practice	Grain yield (t/ha)			Straw yield (t/ha)			Additional grain yield (t/ha)			Additional straw yield (t/ha)			Additional input cost ($)	Additional gross income/ha ($)			Command area in different years
Year	2001	2002	2003	2001	2002	2003	2001	2002	2003	2001	2002	2003	2001–2003	2001	2002	2003	2001, 02, 03
T-1	2.13	1.52	2.10	2.92	1.58	2.35	–	–	–	–	–	–	Nil				
T-2	2.30	2.30	2.25	3.01	2.61	2.42	0.17	0.78	0.15	0.09	1.03	0.07	Nil	20.7	108.5	18.0	5, 5, 3
T-3	2.68	2.80	2.85	3.43	2.90	3.25	0.55	1.28	0.75	0.51	1.32	0.90	15	71.7	169.8	102.3	3, 3, 4
T-4	3.05	2.82	2.90	3.64	3.25	3.22	0.92	1.3	0.80	0.72	1.67	0.87	15	117.0	179.7	107.1	3, 5, 6
T-5	3.52	3.62	3.80	4.27	4.20	4.18	1.39	2.1	1.70	1.35	2.62	1.83	20.5	182.6	288.6	227.3	7, 10, 10
CD at 5%	0.35	0.39	0.29	0.41	0.44	0.38											

Additional cost includes cost of fertilizer and difference between cost of local variety and improved variety. It does not include cost of transplanting which is family labour and has nil opportunity cost

*T*1: local variety, direct sowing no fertilizer outside command; *T*2: local variety, direct sowing no fertilizer inside command; *T*3: local variety, direct sowing with recommended fertilizer inside command; *T*4: local variety, transplanted with recommended fertilizer inside command; *T*5: high yielding variety, transplanted with recommended fertilizer inside command sowing of local variety inside the command itself increased yield to the tune of 51.3% compared to the direct seeded local variety outside the command. This was due to the continuous water availability due to seepage from rainwater harvesting structures. The higher water level in the fields inside the command area is shown by Fig. 5. Maximum grain yield was obtained by the adoption of complete improved package with 65.2%, 138% and 81% increase in yield compared with the adoption of farmers' practices in the year 2001, 2002 and 2003 respectively. It revealed that assured water supply through water harvesting structures and other improved package of practices are necessary to exploit the full potential of high yielding variety in rainfed areas, which faces dry spell during the critical period. The results are in line with those of Singh (1995), Pandey et al. (2000) and Prasad et al. (2001).

Different levels of adoption of package of practices gave different returns and this can form a guide for persuading farmers to adopt different levels of technology compatible to their economic conditions. Results also suggests that the crop production programme should be initiated hand to hand along with water resource development in watershed management programmes to utilize full potential of the water resources. For achieving the full potential of the water resources in terms of economic returns, total package of practices, viz., high yielding variety, transplanting and fertilizer application should be adopted, which gives a 90% increase in crop yield. Where adoption of full potential is not possible, the farmers should be encouraged to go for adoption of high yielding varieties, fertilization and transplanting in that order to get more benefits as transplanting with local variety do not show any significant increase in yield levels (Kannan et al. 2006)

3.3.2 Rabi Crops

The farmers increased the area under rabi and summer crops in second and third year (Table 7) as they were encouraged by the water availability in tanks and wells. Thus,

Table 7 Area and productivity of different crops in the command

Crops	Area, ha (yield, t/ha)		
	2001–02	2002–03	2002–03
Kharif			
Rice	18 (2.3–3.52)[a]	23 (2.3–3.62)[a]	23 (2.25–3.8)[a]
Rabi			
Rice	0.8 (3.1)	0.1 (4.0)	0.25 (4.0)
Potato	0.33 (20.0)	2.5 (11.0)	3.2 (20.0)
Tomato	0.03 (8.6)	0.75 (15.25)	0.44 (15.0)
Pea	0.5 (0.6)	–	0.39 (1.125)
Wheat	0.5 (3.1)	–	1.32 (1.75)
Brinjal	–	0.3 (15.0)	0.12 (10.0)
Cucurbits	–	0.2 (10.0)	0.4 (10.0)
Chilies	–	0.3 (5.2)	
Summer			
Ladiesfinger	–	0.5 (3.2)	
Cucurbits	–	0.7 (12.5)	
Other vegetables	–	0.5 (10.0)	1.0 (10.0)
Maize	–	0.3 (3.1)	0.25 (40,000 cobs)
Cropping intensity	112%	126%	132%

[a]Rice yield obtained from different cultivation practices as per Table 6

a rainfed farmer will shift to irrigated agriculture once the reliability of the system is established. A properly designed tank cum well system provides that dependability which is evident from the increase in cropping intensity from less than 100% in pre project period to 126% in second year and 132% in third year. Cropping intensity is the ratio between gross cropped area and net cropped area. The cropping intensity is expected to increase further in future once the farmers are in position to invest more on seed and fertilizer in the *rabi* crops. Another worth noting fact is reduction in area of post monsoon rice, which reduced from 0.8 ha in first year to just 0.1 ha in second year. In the first year, the farmers being the rice eater, the first preference was *summer* rice. But in the subsequent years they shifted to vegetables as they got more benefits from them. The farmers also went for multiple use of crops by raising ducks, pisciculture, and planting of horticultural crops like papaya, pumpkin and even pigeon pea. The pigeon pea although was of very small quantity provided an additional intake of protein for these farmers.

Table 8 Abstract of economic analysis of tank system for crop year 2001–02, 2002–03 and 2003–04

Sl. no.	Item	Amount in dollars ($)		
		2001–02	2002–03	2003–04
1	Total gross additional return in kharif compared to out side command area which includes labour cost which is family labour	1,970	4,890	3,550
2	Total additional inputs used in command during kharif (seed cost $40, 55 and 100; fertilizer cost $195, 265 and 265; pumping cost $0, 110 and 0 in first, second, and third year respectively)	235	430	365
3	Total net return in kharif including labour cost which is family labour	1,735	4,460	3,185
4	Gross return from different rabi and summer crops	690	3,680	7,115
5	Cost of inputs in rabi and summer crops including pumping cost (seed cost $100, 565, and 1110; fertilizer cost $35, 115, and 155; pumping cost $30, 135, and 220/– in first, second, and third year respectively)	165	815	1,485
6	Net return from rabi and and summer crops	525	2,865	5,630
7	Net return from multiple use (fish, eggs and vegetable on the embankment of ponds)	80	80	80
8	Cost of maintenance	Nil	Nil	110
9	Total net returns from kharif and rabi (3 + 6 + 7–8)	2,340	7,405	9,005
10	Total expenditure on tanks and wells		19,180	
11	Percent of investment recovered in 3 years			97.75%

Total expenditure on tanks and wells mean all capital expenses incurred to construct six tanks inclusive of surplus structures and five wells

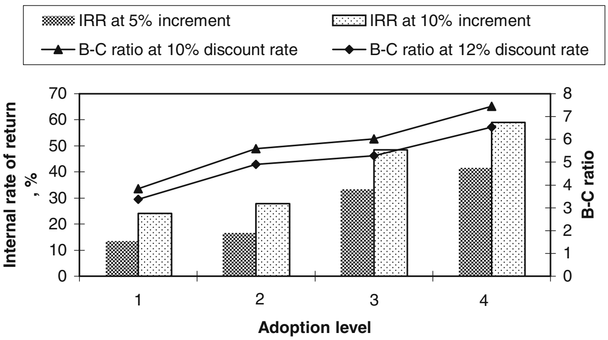
3.4 Economic Impacts

Table 8 presents the abstract of economic analysis of the system in the first three years of its existence. Percent of investment recovered in three years was 97.75% by adoption of improved package of practices, taking up additional cropping and multiple use of tank. Figure 11 presents the internal rate of return and benefit cost ratio calculated on discounted net worth basis for different percentage level of adoption of package of practices by the farmers. Results indicate that with 5% increment rate, the IRR is 13.4% at the present level of adoption of technology. Thus even at minimum level, the IRR is about 2.4% more than the prime lending rate of Indian banks and 3.4% more than the lending rate for agricultural purposes. Thus for these micro water resources, even partial utilization gives a better return in comparison to major and medium irrigation projects where the large gap between potential and utilization of water resources makes the system uneconomical. At a discount rate of 10% which is the prevalent bank lending rate, the benefit cost ratio at present level of adoption of the package of practices was found as 3.63 which increases with increase in the level of the adoption of the crop production technology as shown in Fig. 11. The economical analysis indicates that the system is economically sound. Although this analysis do not include the cost of labour as there is only family labour involved and it has no opportunity cost at present, but the higher values of IRR and B–C ratio shows that the system will remain a viable financial proposition after accounting the family labour cost also. However given the poor resource position of the farmers, the farmers cannot afford to build up these systems on their own at a cost of US $426 per ha and will need subsidies from the government. Since the system has to be constructed for a community and not at individual level, and banks rarely finance community projects, the government has to intervene and execute these projects on a build and transfer basis. This method of execution and transferring to farmers association is being used in India under watershed management program. Similar method has been used here also and the system has been transferred to the people.

3.5 Social and Institutional Impacts

A water resource user association has been formed to manage the created water resources. Two 3.5 hp portable irrigation pumps have been given to the association,

Fig. 11 IRR and B–C ratio for different levels of adoption of package of practices



which are given on hire to members as well as non-members on different rates. While the rate for members is US $0.22 per hour, it is US $0.55 per hour for non-members. The membership fee and this hire charges is being deposited in the account. Assuming 200 pumping hours for members and 100 for non members, the annual collection will be about US $100. The annual membership fee of US $1 from about 50 members will be another US $50. Thus annual collection will be US $150 and in 3 years it will be US $450, sufficient to buy new pumps once the pumps are withdrawn after completion of the project. Interaction with farmers indicated that the farmers' attitude towards the water resource development is very positive. However, the adoption of the practices is constrained by availability of inputs, poaching of produce, and problems in guarding of the fields from grazing and wild animals. Fields located near the forest are threatened by elephants. This is a major constraint to the adoption of the *rabi* crop. Although grazing by roaming cattle is a problem, this can be manageable when a contiguous area of about 20–25 ha is irrigated by a series of tank and wells as done in this case, because everybody in the village becomes a stakeholder and social fencing concept works as it happens in canal commands.

4 Conclusion

The rainwater management through tank and wells has potential of creating micro level water resources for providing reliable round the year irrigation, where the water stored in the tanks as well as seepage water reharvested through downstream open dug well is utilized. This irrigation system can be created and managed by locally available skills. The investment on this irrigation system can be recovered back within a few years. The internal rate of return of such systems is more than the prime-lending rate of the Indian banks even at the initial level of utilization of water by improved cropping practices. The economic efficiency of the system will further improve with enhancement of potential utilization percentage. The system has potential of being another tier of water resource development in addition to major, medium and minor irrigation systems, which can be created through National Rural Employment Guarantee Program, a flagship program of Government of India to provide minimum 100 days of work to rural population.

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