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Economic evaluation of irrigation through water harvesting tanks in Malwa region

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ABSTRACT

The study confirmed that the activity of excavation of farm ponds on the individual farmer's field was extremely useful in turning the mono-cropped area into multi-cropped/crop diversified area and improving the farmer's income and, thus, his/her standard of living. The financial parameters clearly indicate that the water harvesting tanks have tremendous potential in improving the income level of the farmers by turning the mono-cropped areas into multi-cropped areas and helping in stabilizing the farming in the zone. It was also found out based on the economical evaluation of these tanks that the loss of income due to the land encroached by a larger size of tank would be offset by generation of income from crop productivity enhancement and increased water availability. Farm ponds in the individual farmer's fields in the Malwa region will play a vital role in irrigation the crops and improving the productivity of these areas.

1. INTRODUCTION

In Malwa region, it is hypothesized that construction of a water harvesting tank in the farmer's area is not economically viable and the farmers do not get any direct or indirect additional benefit except ground water recharge and this makes the use of water harvesting tank economically unviable for irrigating the crops. This is mainly due to higher initial cost and lesser quantity of stored water as percolation rate is sometimes very high (Singh, 1993; Ranade *et al.,* 1993 and Ranade *et al.,* 2001). Further, the construction of tank would (i) increase the cost of production (due to expenditure incurred for the construction of water harvesting tank); (ii) submerge a portion of cultivable/degraded land without any extra benefit and (iii) make the farmers to pay the loan installment if he borrows the loan for the construction of the tank and if appreciable production is not achieved/increased thus not sufficient enhancement in the farm income). Various studies (Agarwal and Narain, 1997; Ariyabandu, 2001 and Rana and Gupta, 2010) in other regions of the country have been made showing positive impact of rainwater harvesting on socio-economic conditions in hilly region, however, no information is available for Malwa region. Since not much information is available on this very important aspect, a study under ICAR funded *ad hoc* project on "Rainwater management through economically feasible water harvesting tanks in Malwa region" was carried out during 2005-2008. Economic feasibility of the water harvesting tanks constructed in a portion of the land holding of the farmers in Malwa region was performed. The tank facilitated better rainwater management and improved crop productivity in the region. One of the objectives of the study was to estimate the internal rate of return (IRR) in order to assess the economic viability of the water-harvesting tank over the investment and to examine, from the farmer's point of view, whether farmers should opt for this activity or not and whether these structures give sufficient returns to repay the loan if farmers borrowed loan from a financial institute. To achieve the above objectives, site selection and construction of water harvesting tanks was carried out before the detailed study. Since rainwater-harvesting technology is highly location specific, before the construction of water harvesting tank, it was ensured that the collected water in the tanks remained stored for sufficient period and the site was suitable for storing the water with almost meager/less rate of percolation. Before the start of actual project work, the detailed mechanical analysis and infiltration studies were also carried out to get an idea about the seepage rate. The depth wise mechanical analysis of different sites indicates that at each site, the soil is clayey in nature. Since it is a heavy deep clayey soil with very low permeability, there are chances that water would remain in the tanks for longer time, which would be made available for irrigating the crops in adjoining fields. The detailed information of site selection criteria are reported elsewhere (Ranade, 2010). During 2005-06, four tanks were constructed. Manohar tank, one of the tanks, was constructed in a gullied portion with a provision of gabion outlet to control further expansion of gullied portion and for safe disposal of excess runoff water. Three excavated tanks were constructed in the low lying areas. The cultivated fields adjacent to water harvesting tanks were irrigated within one year after its construction using available means of irrigation with the farmers. The different crops *viz.* Soybean during *kharif* and Wheat and Gram during *rabi* were grown in these fields. The tanks utilized the gullied portion or other low lying portions of the cultivated fields effectively. While gabion in outlet was provided to control further expansion of the gullies and for safe disposal of the excess water in one of the tanks, other excavated tanks were not provided additional outlet as these were located in existing drainage lines and disposed off the excess runoff without any problem. The cultivated fields adjacent to water harvesting tanks were irrigated within one year after their construction using available means of irrigation with the farmers.

The sites for the construction of water harvesting tanks were in Dakachya micro-watershed (22°51'28" latitude, 75°57'58" longitude). This area represents a topo-sequence of Malwa mainly consisting of medium and deep soils of Sarol series, which includes both medium (30 to 90 cm) and deep (> 90 cm) dark grayish brown clayey soils. The soil is typical Vertisol derived from basalt and clay loam texture. The dominating clay mineral is montmorillonite with high Base Exchange capacity and enormous shrinking and swelling property. The soils are highly fertile and rich in $CaCO_3$ nodules. The soils are highly retentive of moisture and become almost impervious when saturated, thus having very high runoff potential. This makes the black soil of Malwa region highly erodible in nature particularly very susceptible to both splash and rill erosion and occasionally to sheet erosion.

Two types of tanks have been constructed under the scheme, i) Construction of four excavated type water harvesting tanks and ii) Construction of one excavated cum embankment type water harvesting tank. The details of these five tanks are given in Table 1.

2. METHODS AND MATERIALS

Economic Evaluation of Irrigation Through Water Harvesting Tanks

Annual cost of the structure and irrigation infrastructure (cost of investment) was worked out considering the fixed costs and variable costs for the tanks constructed during 2005-06 and 2006-07. The economic analysis was conducted for various newly constructed water harvesting tanks of different shapes, sizes and storage capacities under this scheme at Dakachya. The different crops *viz.,* soybean during *kharif* and wheat and gram during *rabi* were irrigated using diesel-operated pumps and electric pumps of 5 H.P. The details regarding frequency of irrigation, area under different crops and amount of water per irrigation were used to work out the total quantity of water utilized during the entire season. The quantity of water delivered to the farms was measured using the time of operation of pump and discharge through pipe at exit point using a calibrated 200 lit drum and stop watch to calculate the time required to fill it.

The cost of excavation, construction of inlet and outlet, pump set, pipes and its accessories, cost involved in installation of pipeline, vegetative measures *viz., Vetiveria zizanioides, Dicanthium annulatum* etc. for side bund protection employed in the tank, operation and maintenance cost and opportunity cost of the land were considered as fixed cost. The variable cost was considered as the costs of fuel and labour used for pumping and irrigation of the crops.

The total cost of investment involved in construction of the structure was amortized over a period of 20 years at 8.75% rate of interest to calculate the annual cost (Narayan

Table: 1
Particulars of various tanks constructed during 2005 and 2006

Particular	Tanks				
	Manohar	Abhyankar	Prasanna	Sandeep	Chain Singh
Type of tank	Excavated cum embankment	Excavated	Excavated	Excavated	Excavated
Storage capacity (cu m)	7458	2723	2938	3055	2396
Land use	Waste/gully portion	Cultivated	Cultivated	Cultivated	Cultivated
Cost of construction (Rs)	263000	200000	161820	161100	151875
Year of construction	2005	2005	2005	2005	2006

et al., 1988). The amortization of the constructed cost was estimated using the formula given as:

$P/A = \{(1+i)^n \; 1\} / \{i(1+i)^n\}$

Where, i = rate of interest; n = Number of years; P = investment cost of the tank; and A = amortized cost of the structure (annuity factor).

The land value of the constructed area under water harvesting tank was assessed as ₹ 5000 ha^{-1} $annum^{-1}$ considering the mono-cropped area and the net return from the soybean crop grown in the same area. The annual operation and maintenance cost of the water harvesting tank was considered as 2% of the total investment cost. The cost of irrigating per ha was worked out separately for each crop on the basis of actual amount of water utilized for irrigation, pumping hours and consumption of diesel in case of diesel pump. However, for electric pump, the prevailing electric charges actually paid for temporary connection for two months are considered for calculating the cost per irrigation.

Cost of Cultivation, Net Investment, Gross Return, Net Benefit for Each Crop

Gross incomes from crops were computed based on the prevalent market rates during 2005-06. Net returns were worked out after deducting the cost of cultivation. Cost of cultivation of crops was worked out taking into account the cost of land preparation, sowing, seed, fertilizer, irrigation, weeding, plant protection, harvesting, transportation of agricultural produce for disposal in market as well as including depreciation on pump sets etc.

3. RESULTS AND DISCUSSION

Economic Evaluation of Various Water Harvesting Tanks

The general information (base line information) regarding the details of water utilized, area irrigated by utilizing the stored water from various water harvesting tanks constructed under the scheme was used to estimate cost of irrigation ha^{-1} cm^{-1} of water application. Table 2 and 3 show fixed cost and average variable costs involved in the constriction of tanks and their use during 2005-06 and 2006-07, respectively. The land value for Manohar tank was considered as zero because it was constructed in gullied portion which was not being utilized for any crop production.

The construction cost was amortized over a period of 20 years at 8.75% rate of interest. Thus, the cost of irrigation from each tank was estimated (dividing total variable cost by total quantity of water used during the year). This varies depending upon the area, no. of pumping hours, diesel consumption, electric charges, repair and maintenance cost and labour requirement.

Table 4 presents the economics of different irrigated crops. The cost of cultivation for the irrigated crops was

Table: 2
Cost of irrigation from Manohar tank

A. Fixed Cost	(₹)
I. Cost of construction of water harvesting tank (excavation, inlet and outlet) of irrigation infrastructure (7458 cum)	
a. Cost of bulldozing	39060.00
b. Cost of earth work by JCB	149175.00
c. Cost of inlet and outlet	74765.00
d. Cost of pump set and pipes	50527.30
Total cost of structure	313527.3
i. Construction cost amortized over a period of 20 years @ 8.75% annual Interest rate P/A = $\{(1+i)^n - 1\} / \{i(1+i)^n\}$	33748.9
Total fixed cost $annum^{-1}$	347276.2
B. Variable Cost	
a. Cost of diesel used in *rabi* season 410 lit @37/lit	15162.75
b. Cost of diesel used in *kharif* season 104 lit @37/lit	3831
c. Electricity charges in *rabi* Season	3508
Total annual fuel cost	22501.75
II. Labour cost 25 man days @ Rs.70 $manday^{-1}$	1750
III. Repair and maintenance cost @ 2% of the total investment cost (annual)	6270.5
Total variable cost	30522.25
Total cost $annum^{-1}$	64270
Total quantity of water used during the year (ha-cm)	75.8
Cost of irrigation $ha\text{-}cm^{-1}$ of water =Total variable cost/Total quantity of water used	402.7

Table: 3
Cost of irrigation from Sandeep tank

A. Fixed Cost		(₹)
I. Cost of construction of water harvesting tank (excavation, inlet and outlet) of irrigation infrastructure (3055 cu.m.)		
a. Cost of earth work by JCB		161100.00
b. Cost of pump set and pipes		20000.00
	Total cost of structure	181100.00
i. Construction cost amortized over a period of 20 years @ 8 .75% annual Interest rate P/A = $\{(1+i)^n - 1\} / \{i\,(1+i)^n\}$		19494.10
	Total fixed cost annum^{-1}	200594.1
B. Variable Cost		
I. Pumping hour		
a. Temporary electricity charges		2925.00
	Total annual fuel cost	2925.00
II. Labour cost 25 man days @ ₹70 man-day^{-1}		1750.00
III. Repair and maintenance cost @ 2% of the total investment cost (annual)		3622.00
	Total variable cost	8297.00
	Total cost annum^{-1}	27791
	Total quantity of water used during the year ha-cm	27.9
	Cost of irrigation ha-cm^{-1} of water	297.4

calculated on the actual basis. In case of irrigated soybean, only increase in yield due to irrigation was considered for estimation of net return. Since 2005 was the scanty rainfall year, the *rabi* crops could be grown in the area having stored water in the tank as no ground water was available. Thus, the *rabi* crop could be harvested successfully due to availability and utilization of stored water. Therefore, it is evident from Table 4 that during abnormal year of 2005-06 with no *rabi* crop in other areas, the owner of the water harvesting tank constructed under the scheme, in general, benefited tremendously with net returns. At the same time, irrigation during dry spell to soybean crop increased the yield almost by 4 q ha^{-1}. In Table 4, the cost of irrigation of soybean is considered as zero because normally soybean does not require irrigation water and farmer has to incur any way around 8000/- towards cost of cultivation to get an average yield of 15 q ha^{-1}. However, during 2005, due to prolonged dry spell and scanty rainfall, irrigation was provided from the harvested water and that increased the soybean yield by 4 q ha^{-1} by incurring additional irrigation cost only. Therefore, in the present study, only the increase in yield *i.e.* 4 q ha^{-1} due to supplemental irrigation and the cost of irrigation was considered for calculating the economics of soybean.

It is to point out that during 2006-07 tank water was utilized in conjunction with tube well water for irrigating *rabi* crops to obtain good yield. However, while calculating the cost benefit ratio, the utmost importance was given to pre-sowing irrigation either from tube well or tank water and accordingly the reduction or increase in yield due to pre sowing irrigation is accounted for, based on the data generated from the neighboring farmers (Table 5). Since no irrigation was provided to wheat crop from Abhyankar tank, the yield data was not considered for calculating the B: C ratio. It is very clear that for all the *rabi* crops, higher net returns could be obtained due to irrigation from the stored water. Narayan *et al*. (1988) and Mishra *et al*. (1998)

Table: 4
Economics of different crops and tanks during 2005- 06

Tank	Crops	Additional Yield due to extra irrigation from the tank (kg ha^{-1}) Grain	Straw	Cost of cultivation (₹ ha^{-1})	Irrigation cost (₹ ha^{-1})	Total cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return/ benefit (₹ ha^{-1})
Manohar	Soybean	400	354	-	1812	1812	5812.4	4000
	Wheat	2400	200	6560	2792	9352	29000	19648
	Gram	1200	900	7525	1595	9120	55800	46680
Sandeep	Soybean	600	530	-	1035	1035	8718	7684
	Gram	800	600	7525	3243	10768	37200	26432
Prassana	Gram	800	600	7525	3420	10945	37200	26255
Abhyankar	Soybean	600	531	-	660	660	8718.6	8058
	Gram	980	700	7525	2065	9591	45500	35909

Note: For soybean only increase in yield due to irrigation during dry spell is considered. The yield for other *rabi* crops is also the additional yield enhancement due to irrigation provided from the tank as no crop could be sown in other cultivated fields due to non availability of water.

Table: 5

Overall income earned by farmers by using tank water during 2006-07

Tank	Crop	Area (ha)	Yield (q ha^{-1})	Cost of cultivation (₹ ha^{-1})	Irrigation cost (₹ ha^{-1})	Total cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})
Manohar	Wheat	5.25	27	6880	3273	10153	24300	14147
	Gram	1	7.5	6600	1656	8256	26250	17994
	Garlic	0.625	42	73600	2275	75875	138600	62725
	Vegetable	0.25	250	20000	3792	23792	87500	63708
	Maize+ Barseem	0.5	115	6400	2276	8676	23000	14324
Sandeep	Gram	1.25	20	6600	2560	9160	50000	40840
Prasanna	Gram	1.5	15	6600	759	7359	37500	30141
	Garlic	0.25	40	73600	2276	75876	132000	56124
Abhayankar	Gram	2.25	7	6600	759	7359	17500	10141
	Garlic	0.25	40	73600	2276	75876	124800	48924
	Potato	0.38	188	59200	1518	60718	83472	22754
	Moong	0.25	2	4000	1516	5516	7000	1484
	Vegetable	0.5	230	20000	3792	23792	80500	56708
Chain Singh	Gram	1.5	18	6600	2133	8733	45000	36267

Note: The yield levels are due to conjunctive use of ground water and water harvested in the tanks.

reported similar results for small farm ponds. Similar results have also been reported by Singh (2011) in Bundelkhand region. For the *rabi* crops, particularly gram, it is evident that more area under cultivation/irrigation realized higher net returns. However, if farmer used electric pump, higher net return could be obtained. Due to non-availability of electricity, the farmers were compelled to utilize diesel operated pump which increased the irrigation cost and net return reduced.

Cash Flow

It shows the pattern of the loan repayment and net benefit, a farmer would get if he borrowed the money from the bank to construct the tank. Farmer ultimately would be able to harvest a sufficient quantity if there was water in his field and supplemental irrigation was provided to crops in the adjoining field. Though the life of the tank was considered for all the practical purposes as 20 years for estimating the internal rate of returns, the tank might survive for more than 20 years and its services might also be available after 20 years. As per Table 6, if the farmer fixed the repayment period of the loan at 10 years for digging the tank he would pay equal installment of ₹ 31353/- for the capital and 12% rate of interest on loan amount at the end of the year. The installment shall start from the second year onwards. The farmer can pay the installment of ₹ 31353/- continuously for 10 years from the net benefit of ₹ 175723/- drawn from the tank irrigation during this period. After meeting the maintenance cost of tank and the loan installment repayment, there is still benefit to the farmer

Table : 6

Cash flow (₹) for Manohar tank

Years	Net Investment	Annual maintenance cost	Repayment of principal	Interest cost @ 12%	Balance at the end of the year	Total cost	Benefit from tank	Benefit to farmer
1	313527	0	0	37623	351150	0	0	
2		6270.5	31353	42138	319797	79762	175723	95961
3		6270.5	31353	38376	288444	75999	175723	99724
4		6270.5	31353	34613	257091	72237	175723	103486
5		6270.5	31353	30851	225738	68474	175723	107249
6		6270.5	31353	27089	194385	64712	175723	111011
7		6270.5	31353	23326	163032	60950	175723	114773
8		6270.5	31353	19564	131679	57187	175723	118536
9		6270.5	31353	15802	100326	53425	175723	122298
10		6270.5	31353	12039	68973	49663	175723	126060
11		6270.5	31353	8277	37620	45900	175723	129823
12		6270.5	31353	4514	6267	42138	175723	133585
13		6270.5	0	752	0	7023	175723	168700
14		6270.5	0	0	0	6271	175723	169453
15		6270.5	0	0	0	6271	175723	169453

Table: 7
Cash flow (₹) for Prasanna tank

Years	Net Investment	Annual maintenance cost	Repayment of principal	Interest cost @ 12%	Balance at the end of the year	Total cost	Benefit from tank	Benefit to farmer
1	183164	0	0	21980	205144	0	0	
2		3636.4	18316	24617	186828	46570	17804	-28766
3		3636.4	18316	22419	168512	44372	17804	-26568
4		3636.4	18316	20221	150196	42174	17804	-24370
5		3636.4	18316	18023	131880	39976	17804	-22172
6		3636.4	18316	15826	113564	37778	17804	-19974
7		3636.4	18316	13628	95248	35580	17804	-17776
8		3636.4	18316	11430	76932	33382	17804	-15578
9		3636.4	18316	9232	58616	31184	17804	-13380
10		3636.4	18316	7034	40300	28986	17804	-11182
11		3636.4	18316	4836	21984	26788	17804	-8984
12		3636.4	18316	2638	3668	24590	17804	-6786
13		3636.4	0	440	0	4077	17804	13727
14		3636.4	0	0	0	3636	17804	14168
15		3636.4	0	0	0	3636	17804	14168

(Table 6). A farmer drawing a net benefit of ₹ 175723 pays annual maintenance of ₹ 6270.5 and also the cost of bank loan ₹ 73491/- (loan principal and interest) and is left with ₹ 95961/- at the end of 2nd year. This way the loan gets paid at the end of 12th year and he reaps benefit of ₹ 169453/- thereafter. However, in case of Prasanna tank, though the farmer has to incur meager portion towards payment of principal and interest on the loan to the bank to create this physical asset, he would be benefited only after 12th year. It is to point out, based on the experiences of different tanks that crop diversification due to availability of additional water for irrigation increased the profit of individual farmer.

Internal Rate of Return

The internal rate of return (IRR) was computed to test the feasibility of all the tank irrigation. The internal rate of return was calculated by trial and error method [Gregersan *et al*. (1988), Bhogle *et al.* (1994)]. Based on these calculations, the cash flow charts have been prepared. The internal rate of return was calculated for different planning horizons, *viz.,* 10 years and 20 years. For the 10 year period is relatively lower in all the cases mainly due to the loan installment (Table 8). It could also be seen that in spite of low IRR, farmers were able to get benefit after repaying the installment. However, the IRR of the cash flow is greater for own funds than the IRR of the borrowed fund. Based on the analysis it was revealed that the construction of the tank and recycling of water for irrigation was highly worthy and also economically feasible even if farmers invested from their own fund.

4. CONCLUSIONS

It is very clear that the various tanks constructed under the scheme provided sufficient water not only during *kharif* 2005 season but also during or before planting of *rabi* crop. The farmers utilized the stored water during *kharif* season as well as during *rabi* season. Most of tanks provided one pre sowing irrigation to the *rabi* crops. Since the pre-sowing irrigation requires maximum irrigation water due to cracking pattern and unsaturated soil profiles (10 to11.5 cm ha^{-1}), the irrigation water from the tanks saved at least two subsequent irrigations from other sources *viz.* tubewells.

Table: 8
Internal rate of returns for different tanks

Sl. No.	IRR for Manohar tank	
1	Internal rate of return for first 10 years.	53%
2	Internal rate of return after 10 years of repayment of loan up to 20 years	69%
3	Internal rate of return for the whole 20 years.	54%
4	Internal rate of return considering that the farmer is investing his own capital for digging the pond.	69%
Sl. No.	**IRR for Prasanna tank**	
1	Internal rate of return for first 10 years.	-0.04%
2	Internal rate of return after 10 years of repayment of loan up to 20 years	19%
3	Internal rate of return for the whole 20 years.	10%
4	Internal rate of return considering that the farmer is investing his own capital for digging the pond.	22%

The availability of stored water in the tanks constructed under the scheme encouraged and provided confidence to the farmers to grow even other crops like potato, garlic, brinjal, fenugreek, fodder crops in addition to traditional crops like wheat and gram. It is evident that, during abnormal year of 2005-06 with no *rabi* crop in other areas, the owner of the water harvesting tank, in general, benefited tremendously with higher net return. At the same time, irrigation during dry spell to soybean crop increased the yield almost by 4 q ha^{-1}. However, for the *rabi* crops, particularly gram, it is evident that more is the area under cultivation/irrigation, higher is the net return. If farmer uses electric pump, higher net return could be obtained. However, due to non-availability of electricity, the farmers are compelled to utilize diesel operated pump which increases the irrigation cost and thus net return reduces. The scarcity of surface and sub-surface water was so visible during 2005-06 that very few (about 20%) cultivated area could be brought under cultivation in the entire watershed. Therefore, only those farmers who could store surface water in tanks, could harvest *rabi* crops. Thus, the productivity in this command area increased by many folds in first year as it was a case of no crop v/s good crop due to the tanks construction. The major constraint in growing a second crop in many areas was the lack of suitable irrigation water. The study revealed that storing excess rainwater in dugout farm ponds for utilization during the dry spells of monsoon season or for raising a subsequent crop was a promising way to improve the cropping intensity and crop productivities and to stabilize the farming in the Malwa region.

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