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Impact of rainwater harvesting structures on farm income in north Karnataka - An economic analysis

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ABSTRACT

The study was undertaken with the objective of assessing the impact of rain water harvesting structures (RWHS) on cropped area, cost, returns and income of farmers in North Karnataka. The study was conducted based on primary data obtained from 120 sample farmers belonging to Koppal and Gulbarga districts of North Karnataka. There was a significant difference in the cropped area, cropping intensity and irrigation intensity among the farmers with RWHS in comparison with farmers without RWHS. The cost of cultivation of *tur*, *jowar*, cotton, groundnut and maize grown by farmers with RWHS was higher by 19.74, 13.86, 9.13, 6.87 and 5.81%, respectively compared to farmers without RWHS. Similarly, the net income generated by farmers with RWHS was higher by 48.83, 76.09, 17.06, 26.49 and 87.56%, respectively in *tur*, *jowar*, cotton, groundnut and maize compared farmers without RWHS. The investment on recharge pits and farm ponds was observed to be financially feasible and economically viable compared to *nala bund* which was deduced from the discounted cash flow measures computed for all the three structures.

1. INTRODUCTION

Out of 329 mha of country's total geographical area, 143 m ha is under cultivation, of which 108 m ha is confined to rainfed agriculture (63%) contributing 44% to the total food grain production and supports 40% of the population (Chandracharan *et al.,* 2007). The fate of rainfed agriculture is oscillating with the temporal and spatial distributions of rainfall. Among the options to stabilize and enhance productivity in rainfed agriculture one is conservation of rainwater. Increasing pressure of population, concerns of food and nutritional security, and environmental safety make natural resources management, a key strategy towards achieving sustainability in dry land agriculture. In India, approximately 24 mha-m equivalent runoff is available for harvesting and many indigenous and improved water harvesting practices are available to utilize the runoff (Singh, 2013). Rainwater harvesting (RWH) is an important measure to conserve, develop and utilize the natural resources. An efficient conservation and scientific management of harvested water is crucial for optimum utilization of water for crop production and domestic purposes. Technically, water harvesting means capturing the rain from where it falls. Thus, RWH is conserving the wasted as runoff by storing it in tanks, ponds and lakes and/or as ground water. The main objective of constructing a rain water harvesting structure (RWHS) is to check the rainwater that goes wasted as run-off and conserving it by recharging the groundwater. Water harvesting through RWHS meets several farm needs such as supply of water for irrigation, drinking, animals, fish production, *etc.*

2. MATERIALS AND METHODS

The study was carried out in Koppal and Gulbarga districts of North Karnataka. The aim of this study was to assess the impact of RWHS such as farm-pond, *nala bund* and recharge pits on cropped area, cropping intensity, irrigation intensity, cost, returns and income of farmers from different crops. Snow ball sampling technique was adopted to identify the farmers who invested on RWHS. The farmers who invested on construction of farm pond, *nala bund* and bore well recharge pits, each numbering 30, were selected. The farmers numbering 30 without any RWHS were also selected for better comparison. In total, 120 farmers constituted the sample size of the study. The investment on RWHS was compounded which gave the present value of investment on RWHS at the time of data collection. Amortization cost of RWHS was worked out to know the annual fixed cost component of RWHS. Fisher's t-test was used to analyze the significance of difference in cropped area, irrigated area, cost of cultivation and net return from the major crops between farmers with and without RWHS. Discounted cash flow measures *viz.*, Net Present Worth (NPW), Benefit Cost Ratio (BCR) and Internal Rate of Returns (IRR) were worked out to analyze the financial feasibility of investment on RWHS. The discounted cash flow measures were computed based on the following assumptions:

1. The additional net returns generated from all crops with RWHS were considered as benefits.

2. The investment on RWHS was considered as an establishment cost while the variable cost on RWHS was considered as maintenance cost.

3. The cash flows were discounted at 11% interest rate.

4. The economic life of RWHS was considered as 10 years.

Cobb-Douglas production function was used to estimate the factors determining the gross income of the sample farmers. In order to capture the effect of RWHS, combined production function with RWHS and without RWHS was fitted. The production function took the following form.

$$Y = a\, X_1^{b1} X_2^{b2} X_3^{b3} \ldots\ldots\ldots.. X_4^{b4} \mu \qquad ...(1)$$

Where, Y= Gross return (₹ farm^{-1}), X_1= Labour used (₹ farm^{-1}), X_2=Material inputs (₹ farm^{-1}), X_3= Gross irrigated area (acre), D_1= Possession of RWHS (1=with RWHS, 0, otherwise), a=Intercept, b1, b2…=Regression coefficients, μ=Error term.

The non-linear Cobb-Douglas production function was transformed into linear function by converting all variables into logarithmic form. The function was of the form:

$$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + \ldots\ldots + b_4 \ln X_4 + \ln \mu$$

3. RESULTS AND DISCUSSION

Investment Pattern on Different RWHS

The investment on RWHS was incurred one time while the benefits generated were spread over the years. The investment by farmers on farm pond was highest (₹ 45,270 structure^{-1}) followed by *nala bund* (₹ 33,819 structure^{-1}) and recharge pits (₹ 21,127 structure^{-1}). The amortized cost of investment on farm pond, *nala bund* and recharge pits were ₹ 9,616, ₹ 7,062 and ₹ 4,695 structure^{-1}, respectively (Table 1) for an economic life of 10 years.

The farmers with medium sized holdings invested more (₹ 55,490) on farm ponds in comparison with large (₹ 41,054) and small (₹ 37,012) farmers. The investment on *nala bund* and recharge pits was highest among large farmers (₹ 35,313 and ₹ 26,885, respectively) followed by medium (₹ 33,795 and ₹ 25,273, respectively) and small farmers (₹ 26,433 and ₹ 23,120, respectively) (Table 2). The small farmers had lower percentage share of investment on all the three RWHS because of small size of holding and low level of income.

Impact of RWHS on Cropped Area, Cropping Intensity and Irrigation Intensity

The average size of holdings under rainfed and irrigated situations among farmers with RWHS (4.28 and 5.78 acres) was higher in comparison with farmers without RWHS (3.60 and 3.13 acres). As expected, the fallow land area was higher among farmers without RWHS (0.23 acres) compared to farmers with RWHS (0.13 acres). The percentage change in rainfed, irrigated and fallow land with RWHS over without RWHS was to the tune of 18.89, 84.66 and 43.48%, respectively (Table 3).

The impact of RWHS is visible in terms of additional area under different crops, and also area under irrigation. The average gross and net cropped area among farmers with RWHS was higher (14.86 and 10.06 acres) in comparison

Table:1
Investment pattern of farmers on RWHS

Sl.No.	Particulars	Farm pond (N=30)	*Nala bund* (N=30)	Recharge pit (N=30)
1	Dimension (m)	17.83x13.50x4.30	17.63x2.23x1.6	3.76x3.56x3.76
2	Total investment (₹ 000's)	1358.10	1014.550	633.80
3	Average investment (₹ 000's)	45.27	33.819	21.127
4	Total compounded cost (₹ 000's)	1699.014	1247.852	829.642
5	Average compounded cost (₹ 000's)	56.633	41.595	27.654
6	Total amortization cost (₹ 000's)	288.495	211.887	140.874
7	Amortized cost structure^{-1} (₹ 000's)	9.616	7.062	4.695

Table:2
Investment on RWHS across different size of holdings

Particulars	Farm pond		*Nala bund*		Recharge pit	
	Average investment (₹ 000's)	% to the total	Average investment (₹ 000's)	% to the total	Average investment (₹ 000's)	% to the total
Small	37.012	27.71	26.433	27.67	23.120	30.71
Medium	55.490	41.55	33.795	35.37	25.273	33.57
Large	41.054	30.74	35.313	36.96	26.885	35.72
Total	133.556	100	95.541	100	75.278	100

with farmers without RWHS (7.37 and 6.03 acres). Similarly, average gross and net irrigated area among farmers with RWHS was also greater (9.72 and 5.78 acres) in comparison with farmers without RWHS (5.17 and 3.73 acres). In view of higher cropped area, the cropping intensity was more (147.73%) among farmers with RWHS in comparison with farmers without RWHS (122.10%). Similarly, the irrigation intensity was highest among farmers with RWHS (168.27%) in comparison with farmers without RWHS (138.39%). The percentage change in average gross cropped area, net cropped area, gross irrigated area and net irrigated area were 101.63, 66.83, 88.01 and 54.96%, respectively (Table 3). The farmers who invested on RWHS were able to devote more area for different crops compared to farmers without RWHS. Similarly, the irrigated area was more among farmers with RWHS in comparison with farmers without RWHS. These findings are in conformity with the study conducted by Singh and Jain (2004), Desai (2005), Shwetha (2009) and others who observed that adoption of RWHS had helped in decreasing the area under waste land and in increasing the cropping intensity. Hence, the farmers are encouraged to invest on RWHS.

Cost and Returns of Different Crops With and Without RWHS

The cost components, including variable and fixed costs, were much higher among farmers with RWHS in groundnut, cotton, *tur,* maize and *jowar* in comparison with farmers without RWHS (Table 4). The cost of cultivation of crops among farmers with RWHS in groundnut, cotton, *tur*, maize and *jowar* were ₹ 21,237, ₹ 20,650, ₹ 16,692, ₹ 15,625 and ₹ 12,776 ac^{-1} as compared to farmers without RWHS ₹ 19,871, ₹ 18,921, ₹ 13,940, ₹ 14,767 and ₹ 11,220 ac^{-1}, respectively. The cost of cultivation of *tur*, *jowar,* cotton, groundnut and maize were higher by 19.74, 13.86, 9.13, 6.87 and 5.81%, respectively among farmers with RWHS in comparison to farmers without RWHS. The farmers with RWHS were able to invest more on inputs such

Table:3
Extent of cropped area, cropping intensity and irrigation intensity among farmers with and without RWHS

Sl. No.	Particulars	Farmer with RWHS (N=30)	Farmer without RWHS (N=30)	% change in area with RWHS over without RWHS	t-value
1	Average land holding size (acres)	10.19	6.96	46.41	-
	(a) Rainfed area (acres)	4.28	3.60	18.89	-
	(b) Irrigated area (acres)	5.78	3.13	84.66	-
	(c) Fallow land (acres)	0.13	0.23	43.48	-
2	Average gross cropped area (acres)	14.86	7.37	101.63	25.31**
3	Average net cropped area (acres)	10.06	6.03	66.83	20.53**
4	Average gross irrigated area (acres)	9.72	5.17	88.01	15.08**
5	Average net irrigated area (acres)	5.78	3.73	54.96	20.79**
6	Cropping intensity (%)	147.73	122.10	-	-
7	Irrigation intensity (%)	168.27	138.39	-	-

Note: ** Significant at 1% level, *Significant at 5% level

Table:4
Cost of cultivation of different crops of farmers with and without RWHS ($acre^{-1}$)

Sl.No.	Particulars	Farmer with RWHS (N=90)					Farmer without RWHS (N=30)				
		Maize	*Jowar*	Ground nut	Cotton	*Tur*	Maize	*Jowar*	Ground nut	Cotton	*Tur*
Variable cost											
1	Seeds	530	150	3632	831	160	450	140	3256	885	145
2	Chemical fertilizers	1277	606	1332	1236	1328	1190	570	1197	1150	1150
3	Plant protection chemicals	424	-	775	1790	1429	380	-	670	1425	1340
4	FYM	2390	1772	1970	3000	2655	2482	1725	2242	2780	1800
5	Labour charge	4308	4438	5218	6194	4508	3943	3876	5035	6070	3800
6	Irrigation charges	1170	-	1870	1215	-	930	-	1430	910	-
7	Bullock charge	2726	3222	3253	2875	3368	2861	2430	3131	2490	2670
8	Machine charge	349	225	168	360	190	260	264	145	310	170
9	Interest on working capital	395	312	546	525	406	375	270	513	480	332
	Sub total	13569	10725	18764	18026	14047	12871	9275	17619	16500	11407
Fixed cost											
1	Land revenue	29	28	28	29	27	28	27	29	28	27
2	Land rent	1823	1820	2200	2335	2356	1680	1725	2000	2153	2255
3	Interest on fixed cost	204	203	245	260	262	188	193	223	240	251
	Sub total	2056	2051	2473	2624	2645	1896	1945	2252	2421	2533
	Total cost of cultivation	15625	12776	21237	20650	16692	14767	11220	19871	18921	13940
% change in cost of cultivation of farmers with RWHS over without RWHS		5.81	13.86	6.87	9.13	19.74					
t-value		9.56**	3.61**	10.02**	2.36*	3.23**					

Note: ** Significant at 1% level, *Significant at 5% level as seeds, manures, fertilizers, plant protection chemicals and labour, which resulted in higher cost of cultivation of crops compared to farmers without RWHS.

The farmers by virtue of investment on RWHS were able to generate higher yield in all the crops. The additional yield generated by the farmers with RWHS was 3, 1.5, 2, 1 and 1 q ac^{-1}, respectively in maize, *jowar*, groundnut, cotton and *tur* (Table 5). The additional net income generated by the farmers with RWHS was ₹ 1,416, ₹ 1,324, ₹ 1,312, ₹ 2,041 and ₹ 713 for maize, *jowar*, groundnut, cotton and *tur*, respectively. The percentage increase in net income by farmers with RWHS in maize, *jowar*, *tur*, groundnut and cotton were 87.56, 76.09, 48.83, 26.49 and 17.06%, respectively.

The farmers who invested on RWHS were able to harvest rainwater and store more water in wells resulting in more moisture content in the soil profile. This resulted in higher gross cropped area and gross irrigated area among farmers with RWHS. In addition, the farmers with RWHS invested more on manures, fertilizers and plant protection chemicals resulting in increase in productivity in most of the cultivated crops which in turn helped in getting higher income from these crops. These findings gain support from the study conducted by Desai (2005) and Regar *et al.* (2010) who reported that RWHS has positive impact on crop productivity, cropping pattern and income of the farmers. Similar results were reported by Kumar and Dhawan (1992). Reddy *et al.* (2003) reported that the per capita income increased from ₹ 1,443 to ₹ 1,917 in addition to creation of employment opportunities to the tune of 29,938 man days. Significant difference was observed in net income of all the major crops grown by farmers with RWHS compared to farmers without RWHS.

Financial Feasibility of Investment in RWHS

The results of discounted cash flow measures *viz.*, Net Present Worth (NPW), Benefit Cost Ratio (BCR) and Internal Rate of Returns (IRR) to analyze the financial feasibility of investment on RWHS is presented in Table 6. The NPW of investment on recharge pits was higher (₹ 55,814) followed by farm pond (₹ 53,075) and *nala bund* (₹ 17,907). The BCR was higher for recharge pits (1.21) followed by farm pond (1.20) and *nala bund* (1.08). Similarly, the IRR was higher for recharge pits (29%) followed by farm pond (26%) and *nala bund* (18%), respectively. The payback period for recharge pits was lower (3.5 years) followed by farm pond (4 years) and *nala bund* (5 years). It was observed that NPW was positive, B:C ratio was more than unity and IRR was more than the discount rate indicating that the investment on all three RWHS was financially feasible. The investment on recharge pit was found to be financially feasible and economically viable in comparison with the farm pond and *nala bund*. Hence, the farmers are advised to invest more on recharge pits to reap the benefits of ground water recharge. These findings are in line with the study conducted by Nagaraj *et al*. (2006), Vora *et al*. (2010) and Nagaraj *et al*. (2011), who reported that investment in RWHS is financially feasible and economically viable.

Impact of RWHS on Income of Farmers

The gross returns obtained by farmers with and without RWHS were regressed on the contributing factors such as labour used, material inputs, gross irrigated area and possession of RWHS (as a dummy). The variables included in the model explained the variations in gross returns to the extent of 85.20% (Table 7). The regression co-efficient for labour and material inputs, was significant at 1% level indicating that if the expenditure on both the inputs were increased by ₹ one, the gross returns increased by ₹ 0.536 and ₹ 0.414. The regression co-efficient for gross irrigated area was significant at 5% level. The regression coefficient for RWHS possession (dummy variable) was significant at 1% level indicating that if the expenditure on RWHS was increased by ₹ one, the gross income increased by ₹ 0.219.

Table:6
Discounted and undiscounted cash flow measures of investment on RWHS

Sl. No.	Particulars	Farm pond (N=30)	Nala bund (N=30)	Recharge pit (N=30)
1	Net Present Worth (₹)	53075	17907	55814
2	Benefit Cost Ratio	1.20	1.08	1.21
3	Internal Rate of Return (%)	26.00	18.00	29.00
4	Payback Period (Years)	4.00	5.00	3.50

Table:5
Returns from major crops of farmers with and without RWHS

Sl.	Particulars	Farmer with RWHS (N=90)					Farmer without RWHS (N=30)				
No.		Maize	*Jowar*	Ground nut	Cotton	*Tur*	Maize	*Jowar*	Ground nut	Cotton	*Tur*
1	Average yield (q acre^{-1})	19	6	11	9	5	16	4.5	9	8	4
2	Average price (₹ 000's q^{-1})	0.982	2.64	2.50	3.85	3.773	1.024	2.88	2.758	3.86	3.85
3	Gross return (₹ 000's acre^{-1})	18.658	15.84	27.50	34.65	18.865	16.384	12.96	24.822	30.88	15.40
4	Cost of cultivation (₹ 000's acre^{-1})	15.625	12.776	21.237	20.65	16.692	14.767	11.22	19.871	18.921	13.94
5	Net return (₹ 000's acre^{-1})	3.033	3.064	6.263	14.00	2.173	1.617	1.740	4.951	11.959	1.46
	with RWHS over without RWHS										
6	% change in net income of farmer	87.56	76.09	26.49	17.06	48.83	-	-	-	-	-
7	t-value	10.45**	3.23**	10.90**	2.23*	3.90**	-	-	-	-	-
8	Returns rupee^{-1} of investment	1.19	1.23	1.30	1.68	1.13	1.10	1.15	1.24	1.63	1.10

Note: ** Significant at 1% level, *Significant at 5% level

Table:7
Regression estimates of factors contributing towards gross income of farmers with and without RWHS

Sl.No.	Particulars	Parameters	Co-efficient	t-value
1	Intercept	A	1.448 (0.447)	3.23
2	Labour used (farm^{-1})	X_1	0.536** (0.074)	7.15
3	Material inputs (farm^{-1})	X_2	0.414** (0.060)	6.82
4	Gross irrigated area (acre)	X_3	0.006* (0.003)	2.04
5	With RWHS/Without RWHS (dummy variable)	D^1	0.219** (0.026)	8.15
6	R^2 value	R^2	0.852	-
7	Adjusted R^2 value	R^2	0.846	-
8	F Value	F	165.54	-

Note: Figure in parentheses indicates standard error of coefficients; **Significant at 1% level, *Significant at 5% level

Overall, an increase in the expenditure on labour, material inputs and RWHS over and above the mean level would lead to significant increase in gross return. The additional yield levels of farmers with RWHS were 3, 1.5, 2, 1 and 1 q ac^{-1}, respectively in maize, *jowar*, groundnut, cotton and *tur*. Similarly, the additional net income generated by the farmers possessing RWHS was ₹ 1,416, ₹ 1,324, ₹ 1,312, ₹ 2,041 and ₹ 713 for maize, *jowar*, groundnut, cotton and *tur*, respectively.

4. CONCLUSIONS AND IMPLICATIONS

In India, rainfed agriculture is experiencing an aberration in spatial and temporal distributions of rainfall, which is severely affecting the productivity of different crops, which in turn is affecting the food security. It is a challenge to enhance the productivity of different crops by adopting suitable dry land technologies. Rainwater harvesting remain neglected in many parts of the country and dependence on ground water is increasing. Drawing of groundwater becomes a common phenomenon in rural areas resulting in drastic decline in groundwater level in rainfed areas. This is a serious threat that the rainfed agriculture is already experiencing in the present context. Therefore, there is a need to educate the farmers to take up comprehensive conservation and harvesting of rainwater in order to mitigate water scarcity during critical stages of crop growth. The investment on RWHS would help in providing protective irrigation, besides increasing the ground water table.

Investment on RWHS resulted in enhancing the area under crops, cropping intensity, irrigation intensity, productivity and income from crops. Hence, the farmers in rainfed areas need to be convinced to invest on RWHS to prevent further depletion of ground water level. The investment on recharge pits was found to be financially feasible and economically viable in comparison with farm pond and *nala bund*. Hence, the farmers are advised to invest more on recharge pits to reap the benefits of ground water recharge. Private investment on RWHS is high among farmers with medium and large sized holdings. Therefore, small farmers should also be encouraged to invest on RWHS with suitable incentives from the government. Government support for investment on RWHS along with drip and sprinkler irrigation units is warranted for judicious use of rain water which will enhance the productivity and in turn production of crops in dry land agriculture.

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