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Economic feasibility of refinement or renovation of a water harvesting structure (*Nadi*) - A success story

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ABSTRACT

A study was conducted in Bhilwara district of Rajasthan during the year 2011-2013 to assess the economic feasibility of refinement renovation of a traditional water harvesting structure (*nadi*) under Rastriya Krishi Vikas Yojana project. Four traditional nadies ware selected in two panchayat samities of the Bhilwara district. Crop based experiments were conducted at selected *nadies* before and after renovation of existing *nadies*. Fish demonstrations were conducted after renovation of *nadies* except Ratanpura village of Suwana panchayat samities. Results revealed that average number of irrigations in one ha increased from 1.8 to 3.86 after renovation of existing *nadies* and crop diversification index increased from 0.432 to 0.782 and 0.432 to 0.659 during *kharif* and *rabi* seasons, respectively. Increased water resources and improved technologies increased the productivity by 28 to 48.5% in both the seasons. On an average, ₹ 54,499 annum^{-1} was obtained after one year of renovation of *nadies* with an average B:C ratio of 2.52 against total expenditure of ₹ 35,859. Besides, about 251 to 403 man-days employment was generated as indirect benefit due to water resource development and implementation of improved crop production technologies. The average cost of water storage in the renovated *nadies* was found to be ₹ 6 m^{-3}, whereas, a net return of ₹ 19 m^{-3} was realized by utilizing the stored water for irrigation to crops and fish during the first year of study. Renovation of existing *nadies* increased ground water recharge by 15-41%.

1. INTRODUCTION

The cost of creating one ha of irrigation potential through minor irrigation was estimated at only ₹ 8,000/- as against ₹ 27,000/- for medium and major projects during the VII plan (Samra *et al.*, 2002). Hence, in order to derive equitable benefits at minimum cost and to ensure proper water conservation and emphasis may be shift to construct series of small structures on watershed basis. There are number of small water harvesting structures (*nadi*) used for storing and providing supplemental irrigation to crops for ages in Southern Rajasthan. *Nadi* is the traditional water harvesting structure and is constructed by the farmers with their own wisdom and experience without any technical help. These existing structures are renovated or refined to enhance the capacity inclusion of other components of the system such as west weir and sluice *etc.* The capacity of existing *nadi* is increased by desilting and embankment stabilization for the same watershed. These water harvesting structures conserved natural resources which increased the biomass production, mitigated the ill-effect of drought, recharged ground water, generated employment and improved the socio-economic condition of the farmers (Mittal *et al*., 1986; Grewal *et al.*, 1995; Samra *et al*., 1995, Rana and Gupta, 2010 and Ranade, 2014). In addition to this, these water harvesting structures are easily adopted by the farmers as these are environmentally sound to this and stored water resource provides benefits to the local community. Participatory management of harvested water resources ensure effective utilization, maintenance and sustainable operation of the system.

The principal land use in this region is rainfed agriculture, grassland and forest on slopes and hill tops. The erratic distribution of rainfall, lack of irrigation facilities, soil fertility depletion and small land holdings have made traditional agriculture uneconomical. The increasing bovine population has caused serious problem of excessive cutting and overgrazing of the forest cover leading to hill denulation. Therefore, the present case study has bean focused

upon refinement and renovation of traditional water harvesting structure (*Nadi*) for sustainable crop production in Southern Rajasthan.

2. MATERIALS AND METHODS

A bench mark survey of selected farmers at each location in different Panchayat Samities was carried out to assess the pre-project socio-economic conditions of farmers. Data were collected from 4 farm families, out of which one was small and one was medium farm family whereas two farm families were large. The average life of water harvesting structure (*Nadi*) was found to be 71 years on the basis of surveyed *nadies* (40) in different Panchayat Samities of Bhilwara district of Rajasthan.

Three silted-up water harvesting structures (nadies) were renovated by desilting and embankment stabilization. Outlet for *nadies* was constructed at one location and a west weir was constructed across a small *nalla* to store the runoff water and dispose excess runoff water. Whereas, at three locations grassed waterways with stone pitching was done. Irrigation was done through gravity and lifting by diesel engine pump set at all the four locations. The selection of the four selected existing *Nadies* in different Panchayat Samities is given in Table 1.

The *Nadies* were renovated or refined with an expenditure of ₹ 26,043 to ₹ 44,150 including desilation, embankment stabilization, sluice and stone pitching of grassed water ways or construction of west weir at different locations. The farmers' contribution in renovation or refinement of *nadi* varied from 26 to 40% of total expenditure incurred in renovation.

Table: 1
Details of three selected existing nadies in different panchayat samities

S. No.	Panchayat samiti	Location	*Nadi* Characteristics		
			Catchment area (ha)	Storage area (ha)	Command area (ha)
1	Suwana	Sidadiyas (1)	33	0.25	0.63
2	Suwana	Sidadiyas (2)	08	0.33	3.50
3	Suwana	Ratanpura	10	0.75	6.50
4	Shahpura	Chalaniya	50	5.60	11.50

Crop diversification index (CDI)

CDI was used to assess the changes in the cropping pattern/system due to crop improvement programs (Sharda *et al*., 2005). It is estimated as,

$$\text{Crop diversification index (CDI)} = \sum_{i=0}^{n} pi \log (1/p_i) \quad ...(1)$$

Where, P_i = Proportion of i' the crop in comparison with total cropped area and n = Total number of crop in the *Nadi* command area.

The CDI can attain any value >0 and higher value of CDI is an indicator of better crop diversification.

Estimation of Benefit

Estimation of benefit generated from nadi system of water harvesting and recycling annual costs were worked out taking into consideration both fixed and variable costs. The investment costs on renovation were amortized over a period of 71 years at 8% interest rate considering the life period of the *nadi* as 71 years, using the following equation:

$$\text{Amortized cost (₹)} = \frac{r \times (I + r)^n \times I}{(I + r)^n - I} \quad ...(2)$$

Where, r is the rate of interest, n is the number of years, and I is the investment on the water harvesting structure (*Nadi*).

The opportunity cost of the land used for constructing the pond has been valued at @ ₹ 3000 ha^{-1} $annum^{-1}$, assuming that the net return from dryland areas @ ₹ 3,000 ha^{-1} $annum^{-1}$ in the study area. The annual maintenance cost of the *nadi* was assumed to be 2% of the investment cost. Variable cost of irrigation has been worked out by considering actual diesel cost, hiring charges for pump set, laying pipe line, labour cost incurred for pumping the water for supplemental irrigations.

Water harvesting structures came in to operation in September and October, 2012 and first irrigation was given to *kharif* crops thereafter in *rabi* crops. Data were collected from the command area starting from *kharif* to *rabi* which showed a remarkable difference due to supplemental irrigation along with use of hybrid seed, balanced use of NPK and manure, timely sowing and method of sowing.

3. RESULTS AND DISCUSSION

Yield Improvement and Diversification

Provision of irrigation and improved technologies not only increased the yield of crop but also a considerable amount of diversification of crops took place in the command area of *nadies*. The mean maize yield increased from 2793 kg ha^{-1} to 3748 kg ha^{-1} during the project intervention period during 2012-2013 (Table 2). *In-situ* moisture conservation also took place due to ridging after first interculture operation, timely hoeing and weeding in furrows. These practices help to attained in higher productivity of maize. Similarly, blackgram, sesame and cotton yield increased to the tune of 48.5, 28 and 35%, respectively over farmers practice in *kharif* season (Table 2). Cotton, maize, blackgram and sesame crops were grown by the farmers in cropping sequence during *kharif* season, whereas, wheat, mustard, gram, barley and taramira were taken by farmers during *rabi* season. Wheat, barley, mustard, gram and taramira yield increased to the tune of 33, 34, 31, 37 and 28%, respectively over farmers practice. There was lesser increased in crop diversification during *kharif* season with a diversification index (CDI) from 0.432 to 0.782 as compared to *rabi* season from 0.432 to 0.659 during the year 2012-2013 (Table 3). Yadav *et al.* (2005)

also reported that increased crop diversification due to water resources development.

Economics of Water Storage and Utilization

Total expenditure from ₹ 26,043 to ₹ 44,050 was incurred for developing water resources at different locations (Table 4). The average cost of creating storage for irrigation of one ha with one 5 cm irrigation was ₹ 3,403 which is 50% lesser than average cost incurred in creating one ha irrigation potential through minor irrigation projects (₹ 8,000 ha^{-1}) (Table 4). After that no recurring cost was incurred for harvesting the same quantity of water during the following years. This might be due to the reason that 2% of renovation cost is included as maintenance for irrigating one ha of land with 5 cm irrigation depth. Economics of rain water harvesting and storing in renovated or refined WHS were worked out (Table 4). An average amount of ₹ 6 m^{-3} was incurred for renovation or refinement of WHS. In addition, ₹ 1,818 ha^{-1} spent for lifting water to irrigate crops, would gradually decrease over time till the active life of the WHS, as expenditure of construction remains same, but the net

Table: 2
Crop yield influenced by improved crop production technology under nadi system of water harvesting and recycling

S.No.	Crop	Crop yield at different locations (kg ha^{-1})									
		Sidadiyas (1)		Sidadiyas (2)		Chalania (3)		Ratanpura (4)		Average	
		FP	IM	FP	IM	FP	IM	FP	IM	FP	IM
(A) *Kharif*											
1	Maize	2500	3700	2670	3850	2950	3650	305	3790	2793	3748
2	Blackgram	-	-	535	810	510	725	550	850	532	795
3	Sesamme	325	390	320	400	350	425	330	475	331	423
4	Cotton	2182	2875	2150	2810	2250	3050	2350	3325	2233	3015
(B) *Rabi*											
5	Wheat	-	-	2990	3975	3075	4250	3125	4275	3063	4166
6	Barley	1810	2580	1080	2670	2100	2750	2275	3080	2066	2770
7	Mustard	1536	2100	1490	2050	1650	2275	2150	2550	1707	2244
8	Gram	-	-	980	1375	1150	1550	1175	1650	1102	1525
9	Taramira	525	670	550	675	520	680	530	690	531	679

*FP indicates farmers practice and IM indicates improved practice

Table: 3
Crop diversification index influenced by renovation of nadi at different locations

S.No.	Location	*kharif* season			*rabi* season		
		Before renovation	After renovation	Change	Before renovation	After renovation	Change
1	Sidadiyas (1)	0.432	0.432	-	0.272	0.432	0.16
2	Sidadiyas (2)	0.609	0.618	0.009	0.477	0.575	0.098
3	Chalania	0.58	0.59	0.01	0.578	0.652	0.074
4	Ratanpura	0.67	0.782	0.112	0.556	0.629	0.073

Table: 4
Economic analysis of refinement and renovation of nadi system of rain water harvesting structure at different locations in Bhilwara district

S.No.	Economic indicators	Location of *Nadi*				
		Sidadiyas (1)	Sidadiyas (2)	Chalania (3)	Ratanpura (4)	Average
1	Total cost of renovation or refinement of Nadi (₹)	26043 (23%)	44150 (32%)	32734 (38.9%)	40510 (40%)	35859
2	Present worth of returns of crops (a) *kharif* crop (₹)	28929	50470	77756	50095	51813
3	Present worth of return of Crops (b) *rabi* crop (₹)	6715	15550	47219	73145	3565
4	Total present return of crops (₹) (a+b)	35644	66020	124975	123240	87470
5	Present worth of return of fish (₹)	1025	1155	9375	**	3852
6	Total present worth of returns value (₹)	36669	67175	134350	123240	62634
7	Net present return value (₹)	10626	23025	101616	82730	54499
8	Benefit cost ratio	1.41	1.52	4.10	3.05	2.52
9	Pay-back period (years)	1	1	1	1	1
10	Internal rate of returns (%)	40	52	320	210	126
11	Cost of creating one ha irrigation potential (₹)	2544	3041	3055	4969	3403
12	Cost of creating water resource (₹ m^{-3})	4.42	5.3	5.3	8.64	5.92

*Figures in parenthesis indicate the percentage contribution by the farmers in total expenditure of renovation; **Indicates that fish was not cultivated at Ratanpura *nadi*.

returns continued from agriculture in subsequent years (Table 5). The cost of lifting water for irrigation varied from ₹ 1,818 to ₹ 3385 ha^{-1} (Table 5). The stored water is used to irrigate crops like maize, cotton, sesame, blackgram and wheat, barley, mustard, gram and taramira in *kharif* and *rabi* season, respectively (Table 2). The irrigation was given through gravity flow irrigation and followed by lift irrigation system. During the pre-project period, the annual net present returns were only from agricultural crop in command area of *nadi* which varied from ₹ 4000 to ₹ 30000 annum^{-1} whereas after the project interventions, the net returns varied from ₹ 9601 to ₹ 92241 in the first year 2012-2013. Net returns hectare^{-1} increased remarkably from pre-project year (₹ 4000) to project interventions year. The total present net return value of crops and fish varied from ₹ 10626 to 101616 annum^{-1} and ₹ 1025 to 9375 annum^{-1}, respectively. The cost of creating water recourse for one ha irrigation potential varied from ₹ 2544 to 4969 (Table 4). Therefore, it was concluded that on an average, ₹ 3043/- was spent for creating one ha irrigation potential and obtained by utilizing the water for irrigation to the crops only in 1 year with an average internal rate of return of 126%. Therefore, it could be stated that in *nadi* water harvesting systems, the expenditure cost of water resource development can be recovered in just 1 year only. Apart from this, the average B:C ratio for considering 71 years life period of WHS without any further desiltation was found as 2.52:1, which also indicated the economic viability of the project.

Indirect benefit

The refined or renovated WHS were effectively used for irrigation, fish cultivation and livestock. While, the old *nadies* were used for irrigation and animals consumption. Apart from the direct benefits, there are other indirect benefits of water harvesting and recycling, such as groundwater recharging, reduction in soil erosion, improvement of soil fertility, employment generation, reduction of disparity and social tension etc.

Employment generation

Total employment generated in renovation of WHS and in activities at different locations is shown in Table 6. The renovation works of WHS generated employment from 25-403 mandays of people during one year (2012-2013) at different locations of the district. The employed people hailed from landless, small and marginal land categories and also family members in different activities of farming operations. Maximum number of persons (66-73%) were employed in desilting and shaping of *nadi* embankment and over 20% of the men were engaged in crop demonstrations followed by irrigation in the command area of the *nadi*. About 4.2-5.7% and 4.2% of the total employment was provided through watch and ward activities and irrigation, respectively.

Table: 5
Cost of irrigation for one ha from a water harvesting structure-Nadi (2011-13)

S.No.	Parameter	Cost of irrigation (₹ ha^{-1})			
A.	Fixed Cost	Sidadiyas (1)	Sidadiyas (2)	Chalania (3)	Ratanpura (4)
1.	Amortized cost of excavation of Nadi over a period of 71 year and interest rate 8%	1302	887	525	504
2.	Maintenance cost 2% annual	520	883	655	630
3.	Opportunity cost (₹ 3000 ha^{-1})	300	600	1200	600
	Sub total	2122	2370	2380	1734
B.	Variable cost				
1.	Hiring pump set for 5 days	250	250	250	500
2.	Diesel cost 25 (lit.)	675	675	675	1250
3.	Laying of pipe line	150	150	150	150
	Labour (11)	743	743	743	1485
	Sub total	1818	1818	1818	3385
	Grand Total	3940	4188	4198	5119
	Average	4362			

Table: 6
Employment generated on various activities in nadi command area at different locations (2012-2013)

S.No.	Activities	Locations							
		Sidadiyas (1)		Sidadiyas (2)		Chalania (3)		Ratanpura (4)	
		Mandays	%	Mandays	%	Mandays	%	Mandays	%
1	Digging and shaping of Nadi embankment and mechanical structures sluice, pitching in grassed water ways	174	66.7	294	73	218	66.3	252	70.4
2	Crop demonstration laying (both seasons)	57	21.8	72	17.9	75	22.8	76	21.2
3	Irrigation (diesel engine and pipe line)	10	3.8	15	3.7	12	3.6	15	4.2
4	Watch and ward	15	5.7	15	3.7	15	4.6	15	4.2
5	Fish cultivation	5	1.9	7	1.7	9	2.7	-	-
	Total	251	100	403	100	329	100	358	100

Increased irrigation intensity

Rainwater harvesting has increased the irrigation intensity in command area of *nadis* at different locations (Table 7). Earlier, 2 farmers were hardly able to provide one irrigation in a ha since water was not available to provide more number of irrigations to get good crop yield which 2 farmers were able to give 2-4 irrigations in one ha. But with the renovation or refinement of *nadies*, farmers were able to provide 1.5 to 8 irrigations in one ha. Thus, the average number of irrigation ha^{-1} increased from 1.8 (before renovation) to 3.86 (after renovation).

Table: 7
Impact of rain water harvesting on irrigation intensity in command area of nadies

S.No.	Locations	Number of irrigation ha^{-1}	
		Before project	After project
1	Sidadiyas (1)	0.50	1.50
2	Sidadiyas (2)	2.0	4.50
3	Chalania (3)	0.73	1.45
4	Ratanpura (4)	4.0	8.00
	Average	1.80	3.86

Quality of Ground Water

Water samples were taken from nearby the renovated *nadies* at four different locations. These samples were analysed for suitability of irrigation and are shown in Table 8. Results revealed that ground water is suitable for irrigations to crops under different categories (Wilcox, 1975). Results further indicate that the quality ground water improved after storing the harvested rainwater in the *nadies*.

Ground Water Recharge

Renovation or refinement of existing *nadies* helps to increase the storage capacity through desilting. Increase in storage capacity increase the duration of storage and increase the infiltration rate in to the soil. Consequently, ground water recharge is increased and its benefit was observed in terms of rise of ground water level and % increased in irrigation area (Table 9). Results revealed that rise in ground water level and % increase in irrigation area varied from 1.5 to 4.5 m and 100-150%, respectively. It may be stated that ground water recharge through *nadi* varied from 15-41% over before renovation of *nadi*.

Table: 8
Variation of water quality parameters at different locations and time

S.	Locations	Premonsoon (May)				Post monsoon (Oct)				Winter (Dec)			
No.	(Village)	pH	EC (mm hos cm^{-1})	TA ($mg\ l^{-1}$)	Cl ($mg\ l^{-1}$)	pH	EC (mm hos cm^{-1})	TA ($mg\ l^{-1}$)	Cl ($mg\ l^{-1}$)	pH	EC (mm hos cm^{-1})	TA ($mg\ l^{-1}$)	Cl ($mg\ l^{-1}$)
1	Sidadiyas	7.7	462	140	27	7.3	156	60	6	7.4	165	70	9
2	Sidadiyas	7.6	403	705	12	7.2	175	85	8	7.3	92	95	12
3	Chalania	7.4	136	45	18	7.1	85	55	5	7.2	64	65	7
4	Ratanpura	7.1	124	95	11	6.9	60	25	4	7.1	32	65	5

Table: 9
Effect of renovation of *Nadies* on ground water recharge at different locations of Bhilwara district (2012-2013)

S.No.	Location	Depth of Well (m)	Benefits in terms of rise in water level (m)			Increase in irrigated area (%)
			Before renovation	After renovation	Total	
1	Sidadiyas (1)	15.75	10.9	2.6	13.5	140
2	Sidadiyas (2)	17.30	10.65	1.5	12.15	100
3	Chalania (3)	16.5	11	4.5	15.0	150*
4	Ratanpura (4)	16.35	10.43	4.0	14.43	100**

4. CONCLUSIONS

It can be concluded that renovation or refinement of existing small *Nadies* in Southern Rajasthan were found to be economically feasible as the cost of creating water resource could be recouped within a period of one year from the total income. Results of crop demonstration revealed that even one irrigation of 5 cm during the most responsive stage/critical growth stage of the crops makes a lot of difference when compared with crops grown in completely rainfed condition without any supplemental irrigation. The harvested water in the nadi or on farm reservoir can be used as multi source water for irrigation, domestic use, and fish rearing and thus serve as an integrated farming system. These systems have bean observed to be cost effective and economically feasible in the region.

Almost double returns were obtained by utilization of unit quantity of stored water as compared to the cost of storing unit amount of water. Crop diversification index increased from 0.432 to 0.782 and 0.432 to 0.659 of *kharif* and *rabi* seasons, respectively due to water resource development and implementation of improved crop production technologies, which helped in fertility restoration and sustainable crop production.

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Prof. Jaswant Singh Bali (18.12.1923-21.01.2016)

All the members of the Indian Association of Soil & Water Conservationists, Dehradun were deeply shocked to know the news of passing away of Prof. J.S. Bali on January 21, 2016. Born on December 18, 1923 in a farmer's family of village Gharota (near Pathankot) in Punjab, he obtained his Degrees of Bachelor of Science from Lahore, Bachelor of Science (Agril. Engg.) from Allahabad and Post-graduate courses in the Soil Conservation.

Prof. Bali will be remembered for his work on reclamation of gullied waste lands in Bihar in Damodar Valley Corporation in the 1950s for rehabilitation of the oustees from dams, building ponds and conservation structures. He also worked as chief of all the institutions and establishments of soil and water conservation of Government of India and was Head of Soil Conservation Research & Training Centre Dehradun, Professor at Indian Institute of Technology Kharagpur, Head of Soil & Water Conservation Division of Ministry of Agriculture, and United Nations Consultant in Bulgaria, West Indies, Rome and Malaysia.

It was he who introduced the concept of watershed management in the national programmes of conservation and management of natural resources, and created the expanded version of the All India Soil and Land Use Survey. He also conceived the idea and successfully led the campaign to create the Central Department of Land Resources. He highlighted the problem of profitlessness of Indian farming and introduced the far-reaching concept of Bio-industrial Watershed Management, which combined processing industries and sound marketing with resource protection and bio-production, in order to eradicate rural poverty.

He was a creative thinker, writer and poet. He devoted his entire life towards conservation and sustainable use of natural resources.

He has been conferred with highest awards of the Soil Conservation Society of India, Indian Society of Agricultural Engineers and the World Association of Soil and Water Conservation (in the World Conference held in China). Prof. Bali has remained active in the work of the Soil Conservation for the last 62 years.

Members of the IASWC, in a state of shock on sudden demise of Prof. J.S. Bali, pray to the Almighty God to give eternal peace to the departed soul and strength to the bereaved family to bear this irreparable loss.