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Evaluation of benefits from harvested rain water in farm ponds

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ABSTRACT

Farm ponds constructed in the Navsari Agricultural University (NAU) campus, were evaluated with an aim to quantify the benefits derived and to assess the economic feasibility of pond during 2011. The study in NAU campus was taken up as its watersheds are perfect representation of western coast of India and the developments made act as demonstration for students and farmers. The main benefit was creation of irrigation facility in the uncultivable waste lands. In addition to providing regular irrigation during *rabi* and summer seasons, one or two supplementary irrigations in paddy during dry spells in monsoon season catapulted production levels. Prior to construction of pond, Live Stock Research Station (LRS) used to purchase fodder worth lakhs of rupees, due to lack of irrigation facility. Poor quality drinking water (around 5 dS m^{-1}) was provided to the animals affecting health and milk production. After construction of pond, animals were provided with better quality of drinking water (< 2 dS m^{-1}) from the well located at the boundary of pond which improved animals health as well as production levels. Moreover, pond provides great aesthetic value to the campus. Health cautions denizens, birds of the region as well as many migratory birds were found hovering over the pond. Recreational relevancy coefficient calculated from responses of the sample respondents showed high value for irrigation (0.88), scenic beauty (0.87) and biodiversity conservation (0.87).

The economic benefits from the ponds show, BCR in almost all crops except paddy, was above 2 which underlines the alternate land use by cultivating grasses which have a great demand in dairy farms. Highest BCR was obtained while growing fodder maize and lucerne grass (2.54). Sugarcane and banana, both cash crops, though require more water, recorded BCR of 2.03 and 2.34, respectively. The Net Present Worth (NPW) and Benefit Cost Ratio (BCR) of pond was found to be greater than zero and greater than 1, respectively which proves the worth of ponds. Cost of digging the PG hostel pond and spreading of earth in the low lying fields was ₹ 7.5 lakhs only giving BCR of 17.30. These results prove that ponds not only give several invaluable intangible benefits but also provide very high monetary returns. The results could help the policy makers, planners and researchers while assessing the performance of ponds or other rain water harvesting structures (RWHS) under watershed development programmes.

1. INTRODUCTION

This study is an attempt to evaluate the benefits derived and to demonstrate the multiple uses of ponds constructed in campus of Navsari Agricultural University, Navsari, Gujarat. Navsari is located at 20.95°N latitude, 75.90°E longitude and at an altitude of 10 m amsl. The University Campus is located 3 km away in the West of Navsari city and 12 km East from the historical place Dandi on Arabian sea coast. In spite of torrential rains during monsoon, the region experiences water shortages for irrigating *rabi* and summer crops and deteriorating water quality. To mitigate such irrigation constraints and to overcome impact of climatic changes, construction of ponds was contemplated. Though the investments were made but there was a need to evaluate the efficacy of the costs incurred in constructing these water bodies in terms of their effect on water quality of wells in addition to irrigation as well as aesthetic benefits. Efforts are required to quantify the real term benefits derived and their economic value in the long run. The main objectives of this study were to quantify the benefits derived from the pond and to assess the economic feasibility of construction of such ponds in coastal regions.

Several studies on benefits of ponds have been conducted at different places of India enumerating multiple uses of ponds. Karegoudar *et al*. (2004) highlighted the impact of water bodies on resource conservation and productivity. Dugout pond constructed with calcareous soil lining record minimum seepage rate at different heads and is found to be cost effective technique for reducing seepage losses (Jat *et al.,* 2011). Water recycled from farm pond help in applying supplementary irrigations during dry spells as well as pre-sowing irrigations in *rabi* season that helps in augmenting productivity (Dev and Biswas, 2012 and Samuel, 2010). Wani *et al.* (2006) reported that due to additional groundwater recharge, about 200 ha was irrigated in the post-*kharif* season and 100 ha in post-*rabi* season in vegetables and flowers in Adarsha watershed, Kothapally, Andhra Pradesh. Improvement in water quality due to recharging was also reported by Kumar *et al.* (2008), Mudkavi *et al.* (2009) and Bhargav *et al.* (2006). Samuel *et al.* (2013) found investment on plastic lined water harvesting tank integrated with mixed farming systems in north eastern hills, favorable and affordable as per financial variability criteria (IRR, NPV and BCR). Reddy *et al.* (2003), Bhandarkar (2009), Chandrappa (2004), Shivarudrappa (2009) documented the economic benefits of constructing farm ponds. Gledhill *et al.* (2004) reported that ponds play a major role in ecological, social and aesthetic sense in urban settings. Further, to prove the benefits in the coastal settings, this study was carried out to document and demonstrate the multiple benefits of pond constructed in saline waste lands.

2. MATERIALS AND METHODS

At the advent of Navsari Agricultural University in 2003, two ponds existed in the campus; seven more ponds were dug up at suitable locations of the farm. Out of total nine, two ponds were selected for evaluation studies as it was hypothesized that these ponds constructed on waste lands gave maximum benefits, recharged ground water and acted as a barrier against saline ground water intrusion (Fig. 1). Table 1 gives the location and purpose of construction of ponds. To quantify the benefits derived from the ponds, the required data for the study were collected from both primary and secondary sources. Primary data related to the crop cultivation for the year 2010-11 were collected from various research stations of the University, whereas secondary data on the extent of various rainwater harvesting structures and their construction costs were collected from the reports of Shrivastava and Patel (2009) and Shrivastava *et al.* (2010).

Crops grown and the area under the irrigation command of both the ponds were noted during all the three seasons. Number of supplementary irrigations applied during *kharif* and *rabi* seasons from these ponds were recorded; however, after April, PG Hostel pond got dried completely, whereas, pond water at Pulse Research Station got exhausted in December itself. Crop yield and information regarding expenditure made for growing these crops were collected from the respective Research Farms for calculating the cost of cultivation of each crop. Volumetric mass of teak tree, planted adjacent to pond was estimated by measuring tree girth at breast height with the help of measuring tape. Total tree height was recorded from tip of the crown to bottom of the trunk using Ravi altimeter.

The cost of cultivation per ha of the crops cultivated in the command area of pond were calculated using budgeting technique to the crop year 2010-2011 considering prevailing price of input during the time of their use. The ratio between incremental returns and cost (benefit-cost ratio) for particular crops was considered as one of the important indicators to judge the profitability of cultivating the annual crops.

The financial feasibility and economic worthiness of the constructed pond were studied by using two measures *viz.,* Net Present Worth (NPW) and Benefit Cost Ratio (BCR) (Sharda *et al.,* 2012). The following formula was used for calculation of NPW:

$$NPW = \sum_{t=1}^{N} \frac{B_t - C_t}{(1+i)^t} \qquad ...(1)$$

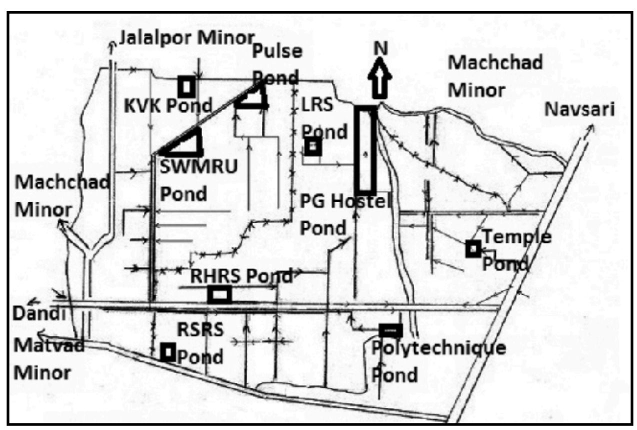

Fig. 1. Ponds constructed at various locations in the campus

Table:1
Ponds selected for evaluation

Location	Type of pond	Purpose	Period of construction
Block B (In front of PG Hostel)	Dug out pond	Utilization of waste land, irrigation, ground water recharge and fisheries	Mar. 2008 - Apr. 2009
Block D (Pulse Research Station)	Dug out pond	Utilization of waste land, irrigation, ground water recharge and fisheries	Constructed in three phases Mar. 2006 - Mar. 2008 - Apr. 2009

Where, B_t = Benefits at time t; C_t = Costs at time t; i= discount rate; and t =life period of the farm pond.

The Benefit Cost Ratio (BCR) was worked out by using the following formula:

$$BCR = \sum_{t=1}^{N} \frac{B_t/(1+i)^t}{C_t/(1+i)^t} \quad ...(2)$$

While computing the benefit-cost ratio, the prime consideration is that while the cost is incurred immediately, the benefits accrue only in the future. For realistic comparisons, all future benefits that will accrue annually throughout the productive life of farm pond are reduced to their present value by multiplying each annuity with a corresponding discounting factor which is given as:

$$\text{Discount factor} = 1/(1+i)\,t \quad ...(3)$$

The total soluble salts were determined using Electrical Conductivity meter in the laboratory as electrical conductivity (EC), expressed as dS m^{-1} to judge the quality of drinking water supplied to animals in the dairy farm.

Aesthetic value of pond was subjected to relevancy rating by randomly collecting information in the form of questionnaire from 15 respondents. They were requested to tick mark against the quality *viz.,* very important, important, neutral, not so important and useless for the assigned parameter. The assigned quality rating is later converted into score on the scale of 5. Later, the responses received from the respondents were analyzed and the relevancy co-efficient of 'i^{th}' indicator (RCi) was worked out by using the formula of Karpagam *et al.* (2011).

$$RCi = \frac{\text{Total score of all the Judges on the '}i^{th}\text{' indicator}}{\text{Maximum score on the continuum* Total number of respondents}} \quad ...(4)$$

Those indicators were used for calculating the relevancy co-efficient to quantify the recreational value.

3. RESULTS AND DISCUSSION

Before construction of these ponds the area was either uncultivable or dependent on water from the wells in the vicinity. At both the locations, where pond was dug, the area was lying as waste lands. After construction of pond in D Block, permanent irrigation facility was created through which irrigation was applied in the crops listed in Table 2, especially during *rabi* and summer seasons. The pond catered to the needs of 9 ha cultivable area. However, there is a scope to increase the irrigated area by adopting superior methods of irrigation such as sprinkler or drip method. Similarly, Table 4 presents the crops cultivated under the command of pond constructed in B Block, where high water requiring crops like paddy, sugarcane and banana are irrigated by lifting water through a 5 hp diesel pump. One or two supplementary irrigations in paddy during long dry spells in monsoon catapults production, especially during initial stages. Perennial crops (Banana and Sugarcane) grown in surrounding fields, are irrigated using drip method of irrigation. In a recent study (Shrivastava and Chatrola, 2012) on climatic variability, it was reported that after first rains, regular onset of monsoon is getting delayed which might be the effect of global climatic changes. Before construction of pond, only saline water was available for irrigation as sea water ingression used to take place during high tide via Creek of Purna River, flowing 3 km north of campus. So, cultivation of such high water requiring crops was not possible. Another major achievement of ponds was providing water for cultivation of grasses/fodder crops. Earlier, Live Stock Research Station (LRS) used to purchase fodder worth lakhs of rupees due to lack of irrigation facility. Total production during 2010-11 from different fodder crops was 1419 q ha^{-1} by using stored

Table: 2
Estimation of returns from crops cultivated in command of pond in Block- D, (₹ in '000)

Crops	Productivity (q ha^{-1})	Cost of cultivation (₹ ha^{-1})	Selling price (₹ q^{-1})	Gross Income (₹ ha^{-1})	Net Income (₹ ha^{-1})	BCR
Castor	8	22.0	5.0	40.0	18.0	1.81
Pigeonpea	9	20.2	3.8	34.3	14.1	1.70
Gram	7	13.5	2.9	20.3	6.8	1.50
Teak	-	-	-	-	-	-

Table: 4
Crops cultivated in 2010-11 and cost of cultivation from Pond in Block- B, (₹ in '000)

Crops	Productivity (q ha^{-1})	Cost of cultivation (₹ ha^{-1})	Selling prize (₹ q^{-1})	Gross Income (₹ ha^{-1})	Net Income (₹ ha^{-1})	BCR
Sugarcane	710	84.6	0.2	171.8	87.2	2.03
Banana	438	93.4	0.5	219.0	125.6	2.34
Paddy	47.8	41.4	1.0	49.4	8.0	1.19
Napier grass	600	58.0	0.2	120.0	62.0	2.06
Fodder maize	700	55.0	0.2	140.0	85.0	2.54
Oat grass	600	55.0	0.2	120.0	65.0	2.18
Lucerne grass	700	55.0	0.2	140.0	85.0	2.54

water. Area under fodder crops could also be increased if irrigated through sprinkler method of irrigation.

Before construction of pond in Block B, dairy animals were supplied with poor quality water (5 dS m^{-1}) from the wells "B" (Fig. 2) and "C" (Fig. 5). Poor water quality would have affected the health of the animals which ultimately affected milk production and monetary returns. Shrivastava and Patel (2009) reported that though new boring was made in 2005-06, its quality was between 3 to 4 dS m^{-1} which, however, was superior from the dairy farm bore but still below drinking water standards. Then, after construction of the pond in the waste land of Block B in 2008, water quality of well "L" improved and remained at around 2 dS m^{-1}, during most part of the year (Fig. 3 and Fig. 4). After construction of pond, water was supplied from the well "L" located at the boundary of pond by means of 400 m long PVC pipe line that conveyed water directly to the barns. Therefore, pond constructed at LRS station, not only benefited from producing fodder for animals but also provided better quality drinking water to farm animals. Though the past data on drinking pattern of animals is not available but Alejandro and John (2001) reported that animals refuse to drink water when TDS is above 3000 which may also cause temporary diarrhea, whereas TDS of 5000 or more affects milk production severely. Before construction of pond, water was supplied from the well "C" of LRS and the animals were supplied with poor quality water above 3000 TDS from January to June (Fig. 5) *i.e.,* for six months during the year. During brief periods of extreme summer, TDS levels of water from the well "C" in dairy farm crossed 5000 mark which used to make the situation dismal. After construction of pond, the health of farm animals was reported better and milk production level enhanced. Average milk production per cow and buffalo showed a clear annual increase after construction of pond and supply of water commenced from the bore "L", adjacent to the pond (Fig. 6). Since all other factors remaining constant, this increase could mainly be attributed to supply of better quality water.

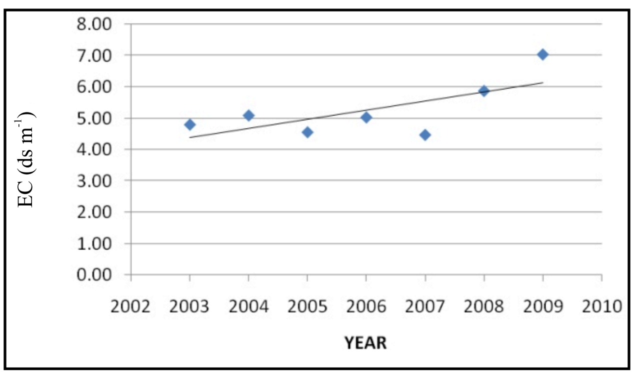

Fig. 2. Decadal water quality of well "B"- Block C, adjacent to dairy

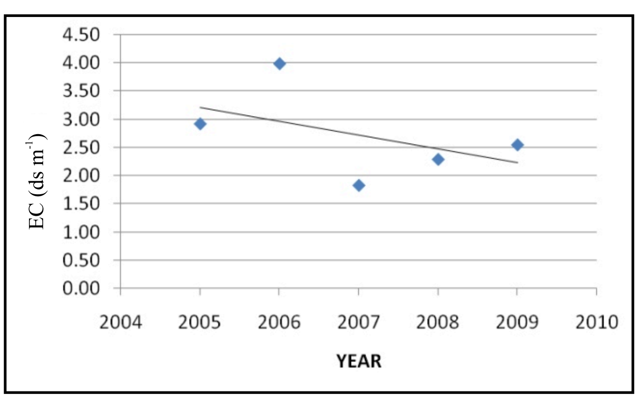

Fig. 3. Decadal water quality of well "L"- Block C, adjacent to pond

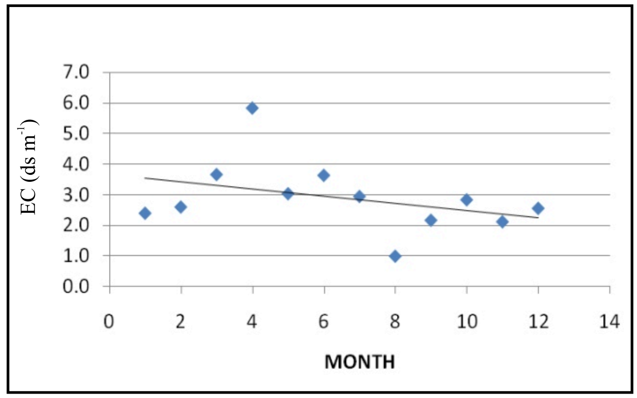

Fig. 4. Annual fluctuations (2010 and 11) in water quality, of well "L" - Block C, adjacent to pond

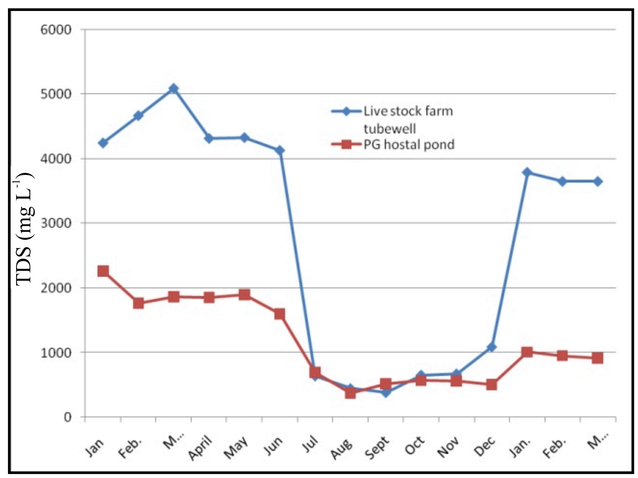

Fig. 5. Comparative water quality (TDS) of farm tube well at LRS, v/s well near the PG Hostel

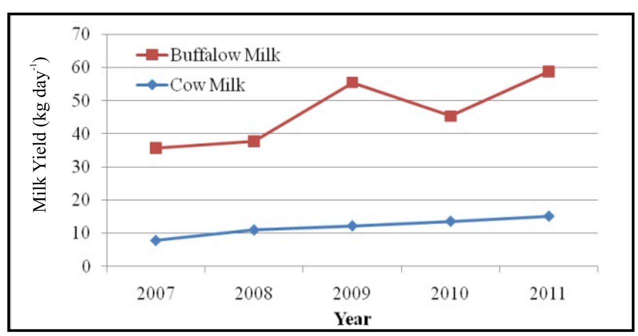

Fig. 6. Annual changes in milk production after supply of water from near the pond

Apart from irrigation, drinking water availability, improvement in water quality, *etc.* these ponds also provided great aesthetic value to the campus. Many migratory birds and birds of the region are found hovering around these water bodies. Result of an analysis of the responses from a sample of people visiting these sites, allocated a score more than 4 out of 5.0 point scale on all parameters. The results (Fig.7) also indicated that irrigation (0.88), scenic beauty (0.87) and biodiversity conservation (0.87) have high relevancy coefficient index while fishing gets the least index value (0.61). The above aesthetic benefits derived from ponds are the intangible benefits which cannot be evaluated in monetary terms but have a definite impact on human and animal's physical and psychological health.

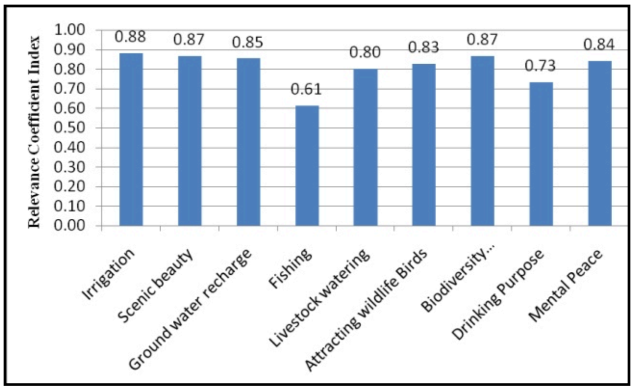

Fig. 7. Relevance coefficient index of the parameters impacted due to pond construction

In addition to intangible benefits from the ponds, the monetary benefits from the ponds were calculated and the results are presented in Table 2 to Table 4. Both the ponds were constructed in the waste lands so if comparison between before and after is done, the gains can be considered as 100%. Tables show the benefits possible due to growing of crops in the command of both the sites and all crops are giving fairly good returns *i.e.,* BCR of more than unity. Moreover, 100 number teak saplings were planted (Table 3) around the pond which are also expected to give very high returns after achieving maturity and that too at virtually negligible cost (Anonymous. 2012). The BCR from the pond at Pulse Research Station was observed to be 15.60, even if we consider only 50% of planted saplings surviving after 20 years and that income is distributed over 25 years period. Table 4 shows BCR above 2 in most of the crops except paddy, which underlines the alternate land use by cultivating grasses which has a great demand in dairy industry. These returns are possible by applying only few number of irrigations from the pond water. Highest BCR of 2.54 was obtained while growing fodder maize and lucerne grass in the pond's command. Sugarcane and banana, both high water requiring cash crops, recorded BCR of 2.03 and 2.34, respectively.

Table 5 depicts the Net Present Worth (NPW) and Benefit Cost Ratio (BCR) of ponds considering cumulative benefits. Since there is negligible silting, it was assumed that there was no maintenance cost. The life of the ponds was considered as 25 years and only monetary benefits from crops were considered. The benefits will be very high if net returns from dairy and fisheries are also added to this. Since the data pertains to the year 2011, NPW was calculated by considering the annualized investment and it was found positive indicating the worthiness of such structures. Similarly, BCR of both the ponds were greater than unity which proved profitability of cultivation using pond water. Cost of digging the PG hostel pond and spreading of earth in the low lying fields was ₹ 7.5 lakhs only resulting in BCR of 17.30. Even, by taking into account the cost of check dam constructed in the downstream the ratio remains sufficiently high 7.40. These results prove that both the ponds gave very high monetary benefits besides giving several intangible benefits.

Table: 3
Estimation of returns from teak plants (100 plants) around the pond

Age	Volume (cu ft)	Market Price* (₹ cu ft^{-1})	Returns per plant (₹ in '000)	Total returns (₹ in '000)
5	25	300	7.5	750
12	60	500	30	3000
20	100	1600	160	16000

Table: 5
Comparison of benefit and cost of multiple uses of pond water

Water body	Location	Benefits (₹ in '000)	Costs (₹ in '000)	NPW (₹ in '000)	BCR
Pond	Pulse Research Station, Block "D" 27	320	575	291 .9	15.60:1
		389 .7#		11 .2#	1.70:1#
Pond	PG Hostel, Block "B" 20, 21	517.8	750	424.2	17.30:1
Check dam			1000*	384 2*	7.40:1*

#Without considering benefits from teak plantation around the pond
*When cost of check dam constructed in the downstream of the pond was also considered

4. CONCLUSIONS

Evaluation of benefits derived from farm pond revealed that creation of irrigation facility in the uncultivable waste lands, catapulted production due to application of supplementary irrigation in crops, especially during *rabi* and summer seasons as well as irrigations in paddy during long dry spells in monsoon season. Supply of better quality drinking water to farm animals improved their health and boosted milk production. In addition, aesthetic beauty in terms of recreational relevancy coefficient values were also observed to be very high. Due to creation of irrigation facility, BCR was above 2 in almost all the crops. Highest BCR of 2.54 was obtained while growing fodder maize and lucerne grass. The Net Present Worth (NPW) of ponds was found to be positive and BCR of both the ponds was greater than unity, which proves the worthiness of the ponds. These results also showed that ponds not only yield very high returns, they also provide several invaluable intangible benefits. The results will help the policy makers, planners and researchers while assessing the performance of ponds or other rain water harvesting structures (RWHS) under watershed development programmes.

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