PROSPECT OF SUPPLEMENTARY IRRIGATION WITH PONDS WATER IN WATER STRESSED BARIND TRACT

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ABSTRACT

Barind tract is a water stressed region located in northwestern part of Bangladesh. Groundwater is the main source of water for irrigation in this region. As yielding of groundwater has increased in recent years, groundwater table has been depleting day by day. Reduction of dependency on groundwater for irrigation by supplementary irrigation with surface water could solve the problem. The prospect of supplementary irrigation with rainwater stored in the ponds is evaluated in this study with compared to existing irrigation practice by deep tube wells for Godagari upazila under Barind tract. The available water in the ponds for supplementary irrigation was determined by subtracting the evaporation loss, percolation loss and water requirement for fish culture from the runoff water towards the pond. Feasibility of the supplementary irrigation was evaluated by determining benefit cost ratio (BCR), net present value (NPV) and internal rate of return (IRR) for the study area. It was found that about 10% irrigation is possible to supplement with pond water which indicates that about 10% groundwater is possible to save by supplementary irrigation with pond water. The economic analysis shows that the benefit cost ratio (BCR) of 5.25 which is highly acceptable. The NPV and IRR obtained from financial analysis of supplementary irrigation with pond water are 2,76,34,852.00 Tk and 29% respectively. Therefore, it can be said that supplementary irrigation with pond water in the study area has a good prospect.

Keywords: *Barind tract, water stressed, supplementary irrigation, pond water, feasibility*

1. INTRODUCTION

The Barind tract is a drought prone waste stressed area with high altitude. The climate of the area is generally warm and humid. Rainfall in the area varies from about 1500 mm to 2000 mm. Temperature ranges from 4^o C to 44^o C (Hossain, et al., 2021a). About 45-70% of the water used for irrigation comes from the ground, and groundwater abstraction and use are both rising globally (Lall et al., 2020). There is evidence that groundwater recharge in the Barind tract of the North-West region is less than the amount withdrawn for irrigation (Hossain, et al., 2021b; 2021c). About 85% of net cultivable area was irrigated by groundwater in the years 2012–2013 in the north-west region (Barind tract) (Mainuddin, et al., 2013). Groundwater supplies provide about 95% of the irrigation water in this area (Kirby, et al., 2013).

Groundwater is abstracting with about 9576 DTWs (deep tube wells) and 162519 STWs (shallow tube wells) for drinking, irrigation, and other uses (Hossain, et al., 2022; Hossain, et al., 2019a). People in Godagari are also use groundwater for irrigation and domestic purpose by means of using deep tube well. Moreover, there are dug wells, re-excavated canals, re-excavated portion of natural *Beel*, re-excavated pond in this area (Hossain, et al., 2020). The gradual lifting of water through deep tube well is affecting the ground water level (Hossain, et al., 2021b; 2019b). In the past 30 years , groundwater irrigation has dramatically increased by factor of 250 (Rashid and Islam, 2013). Water table has decreased as a result of overuse. Ground water abstraction must be reduced by 60% from current levels in the north-west region in order to ensure sustainable use (Mustafa, et al., 2019). To overcome this situation and reduce the dependency on groundwater, the use of surface water would be a solution. The use of ponds water for irrigation will reduce load on ground water. Therefore, the study focuses on the analysis of the supplementary irrigation in terms of availability of pond water for irrigation, economy and financial aspects.

2. METHODOLOGY

2.1 Study Area

The Godagari Upazila under Rajshahi district in Bangladesh was considered as a study area considering the 'high Barind' area. It has area of 472.13 sq km, located in between 24°21' and 24°36' north latitudes and in between 88°17' and 88°33' east longitudes. The study area's typical temperature ranges from 8 to 44° c. The abrupt onset of summer in March is accompanied by a hot North-Western wind and a sharp rise in the mean daily relative humidity from 60 to 85%. For a while in the summer, temperatures as high as 43°c are common (Masum, et al., 2013). The range of rainfall in the area is between 1500 and 2000-mm. When monthly evaporation only varies between 140 and 162 mm in the months of march through may, the highest rate of evaporation is seen (Masum et al., 2013).

2.2 Data Collection

Rainfall data, monthly average bright sunshine hours, and temperature data of the study area were collected from the Bangladesh meteorological department (BMD) during the period of 1991 to 2021. Number of ponds, pond dimensions, total cultivable area of the study, and consumptive use factor for rice in different months were collected from the BMDA.

2.3 Determination of Available Pond Water for Supplementary Irrigation

The available pond water for supplementary irrigation was estimated by subtracting the losses of water (through evaporation, percolation) and minimum requirement of water for fish culture from total accumulated water in the ponds. The accumulated water in the ponds was estimated by using rational formula (eq. 1).

$$Q = CAP \qquad (1)$$

Where, Q is the volume of water from surface runoff (m^3), C is the coefficient of runoff of 0.8 for Godagari Upazila (according to BMDA), A is the catchment area (m^2), and P is the precipitation (m).

The evaporation loss was determined by using class an evaporation pan in the field near the pond (Figure 1a). The pan is exposed and filled with water to mimic an open body of water. The evaporation rate was measured by refilling the fixed-point gauge to the datum and data was recorded regularly. Percolation loss was determined with single-ring infiltrometer (Figure 1b). Minimum water required for fish culture was calculated by multiplying the required depth of water and pond area.

Figure 1: Water loss measurement instruments: (a) USWB class a evaporation pan, (b) Single ring infiltrometer

2.4. Irrigation Requirement

Blaney and Criddle empirical relationship was used to determine the consumptive use and irrigation water requirement was determined by subtracting the effective rainfall from consumptive use as follows. Consumptive irrigation requirement (CIR) = cu – re. Therefore, total water requirement was estimated by multiplying cultivable land area with CIR.

2.5 Feasibility Analysis

Feasibility of the supplementary irrigation with pond water was performed by economic and financial analysis. In this study BCR (benefit cost ratio), NPV (net present value) and IRR (internal rate of return) methods were followed. The benefit-cost ratio (BCR) is used to summarize the overall relationship between a project's relative costs and benefits. The benefit-cost ratio (BCR) was calculated by using following equation (eq. 2).

$$\boldsymbol{BCR = \frac{Present\ value(PV)of\ benefit\ expected\ from\ the\ project}{PV\ of\ the\ cost\ of\ the\ project}} \quad (\mathbf{2})$$

where, PV = 1/(1+r)n, r = discount rate, n = number of year

In the context of an investment analysis, the net present value (NPV) and the internal rate of return (IRR) are both common methods for determining whether or not a project is financially viable. Internal rate of return (IRR) is the discount rate that makes the NPV of a project's cash inflows equal to zero. A project is viable if its IRR is positive and greater than the selected discount rate. Following equations can be used to calculate NPV (eq. 3) and IRR (eq. 4).

$$\boldsymbol{NPV = \sum_{t=0}^{n} \frac{R_t}{(1+r)^n}} \quad (\mathbf{3})$$

Where, Rt = net cash inflow-outflows during a single period t, r = discount rate and n = number of years.

According to Bangladesh bank, a 7% discount rate was used for this study, while 5%, 10%, and 15% discount rates were chosen for sensitivity analysis of this study, taking into account the interests of international readers and funding agencies.

$$\mathbf{0} = \boldsymbol{NPV}\sum_{t=1}^{T}\frac{\boldsymbol{C_t}}{(\mathbf{1}+\boldsymbol{IRR})^{t}} - \boldsymbol{C_0} \quad (4)$$

Where, IRR = internal rate of return, Ct = total cash flow present value, Co = total initial investment and t = time period.

3. RESULTS AND DISCUSSION

The study encompasses the determination of volume of rain water possible to store in the existing ponds, total losses of pond water, irrigation requirement and the possible savings of groundwater by supplementary irrigation with available pond water. The feasibility of this attempt is also analyzed.

3.1 Storage of Rainwater

Annual rainfall of 30 years from 1991 to 2021 is analyzed and observed that the trend of rainfall is increasing at a rate of 26 mm/year with an average of 1121 mm/year (Figure 2). However, the average rainfall after 1996 is 1267 mm/year.

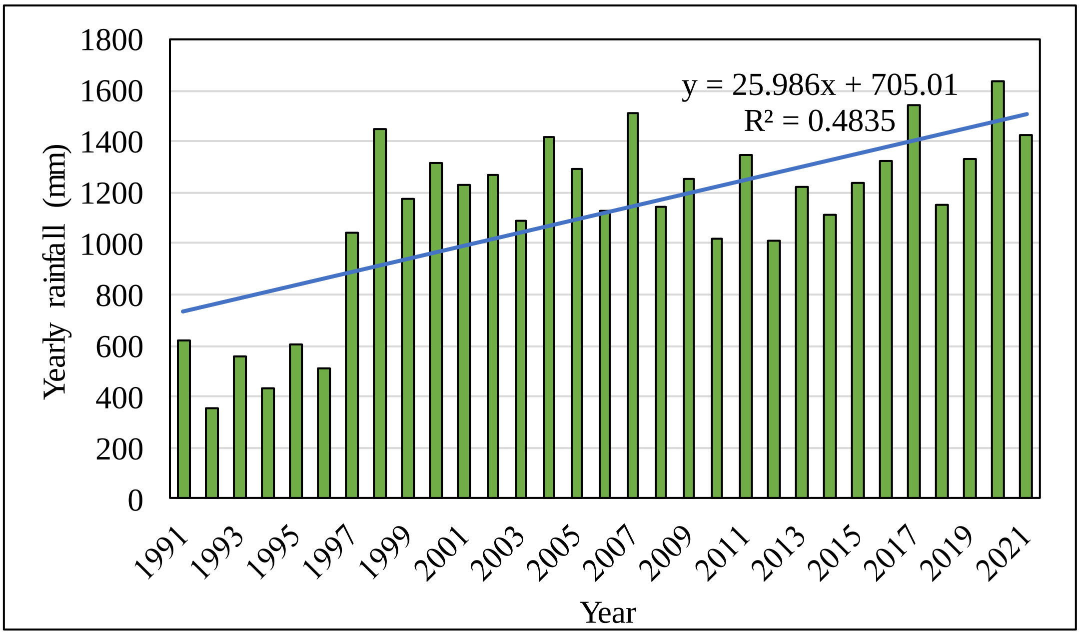

Figure 2: Trend of rainfall analysis for the period of 1991 to 2021.

Figure 3 shows the catchment area and volume of all the ponds under study area. Average catchment area of the ponds is found to be of 2.56 acres (10360 m^2). Whereas, the largest catchment area under the Lole pond's is 4.62 acres (18697 m^2) and the area of the pond is 2.44 acres (9874 m^2). On the other hand, Dorga pond has a smallest catchment area, which is 1.16 acres (4694 m^2) and area of the pond is 1.1 acres (4452 m^2). The highest volume of rain water of 10475.167 m^3/year stored in Lole pond and total storage of pond water is 122119.592 m^3 in a year (Figure 3).

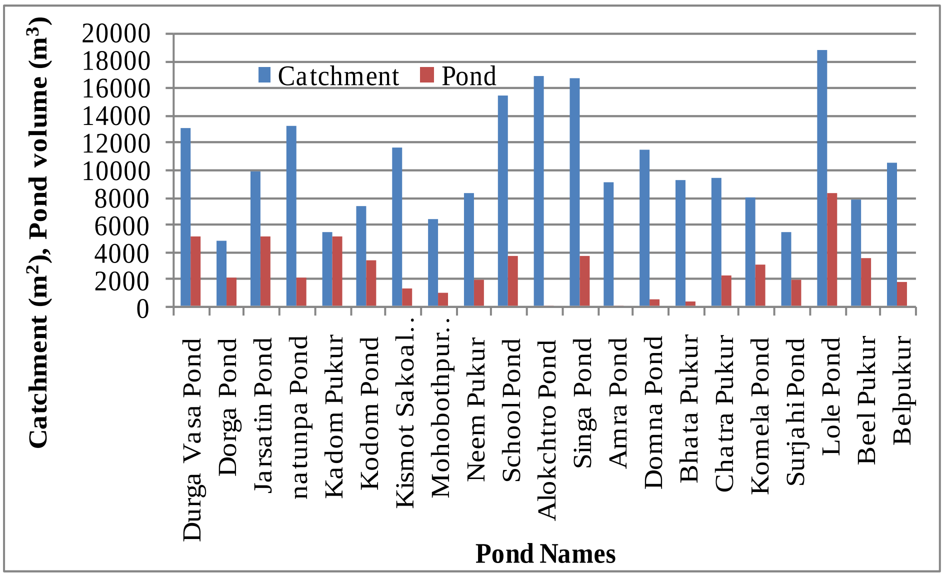

Figure 3: Catchment area and volume of the ponds in the study area.

3.2 Evaporation and Percolation Loss

About 70.23% of the water stored in pond was lost due to evaporation and percolation. And percolation loss was about 46.22% of the total loss and 53.78% of the water was lost due to evaporation. Daily average evaporation loss was 3.03±0.51 mm/day for august and 1.79±0.33 mm/day and 1.8±0.3 mm/day were recorded for September and October. The higher evaporation loss in august is due to high temperature and less rainfall. For the study period the daily average evaporation rate was determined 2.21 mm/day (Figure 4).

Infiltration or percolation loss experiment was conducted beside three ponds i.e. Amra pond, Domna pond and Bhata Pukur and the seepage loss was measured considering three layers i.e. at surface, at 2 ft depth and at 4ft depth. It was found average seepage rate is 2.67 mm/day. Figure 5 represents the average cumulative percolation losses of the three ponds.

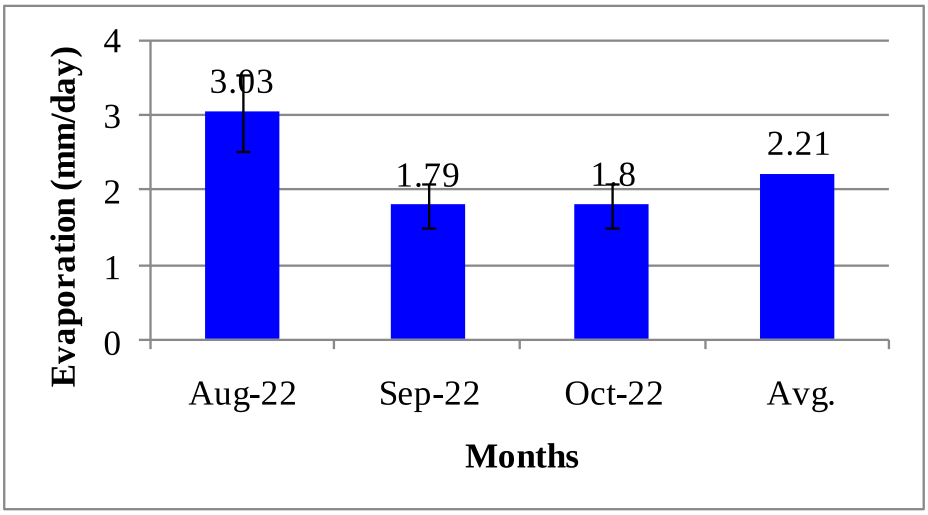

Figure 4: Evaporation of water from August to October, 2022

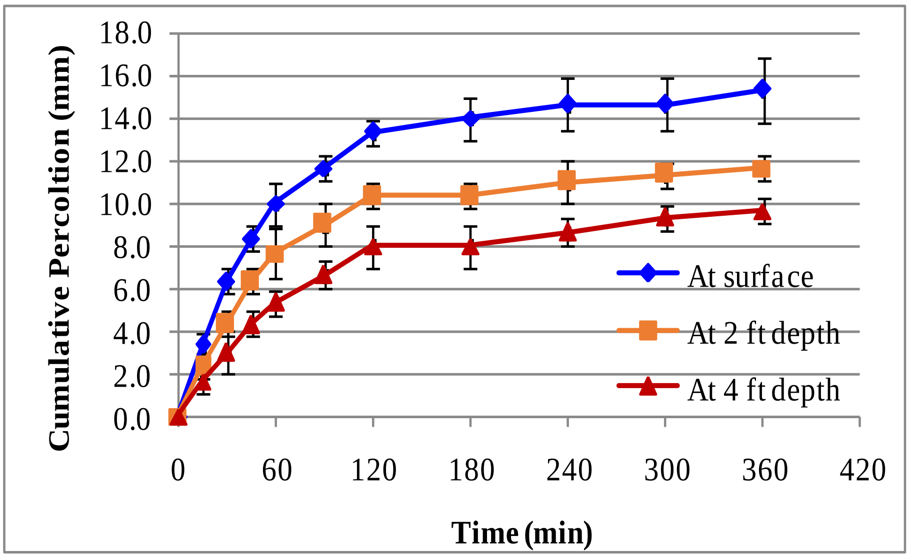

Figure 5: Percolation loss at various depths

In the present study area, there are 21 nos. of pond that had been recently re-excavated. Total combined capacity of the ponds for storage of water was 218326.68 m^3. The largest pond (Lole pond) storage capacity is of 16823.24 m^3 and the smallest pond (Mohobothpur pond) storage capacity is of 2186.91 m^3. Table 1 represents the storage capacity of the ponds and available water for irrigation.

Table 1: Storage capacity and available water for irrigation of the ponds

Pond name	**Storage capacity, m^3**	**Annual runoff, m^3**	**Evaporation loss, m^3**	**Percolation loss, m^3**	**Available water for irrigation, m^3**
Durga vasa pond	11821.58	10189.48	2951.80	2778.60	4459.08
Dorga pond	7873.24	3682.18	1355.46	941.58	1385.14
Jarsatin pond	15498.95	7713.53	2841.30	2388.19	2484.04
Natunpa pond	10180.80	10348.20	2484.60	2270.40	5425.80
Kadompukur	9538.94	4285.30	1480.31	991.49	1813.50
Kodom pond	7120.08	5681.99	1258.29	859.32	3564.38
Kismotsakoalpukur	9361.38	9141.96	2135.28	1867.56	5139.12
Mohobothpur pond	2186.91	4951.90	596.96	427.94	1162.01
Neem pukur	7954.54	6507.30	1678.95	1344.54	3483.81
School pond	14193.78	12094.06	3075.82	2804.36	6213.88
Alokchtro pond	9812.06	13236.80	2122.37	1815.06	5874.63
Singa pond	11367.35	13109.83	2339.67	2009.12	7018.56
Amra pond	10548.39	7110.42	1837.62	1392.44	3880.36
Domna pond	13902.16	8983.25	2999.15	2717.20	3266.90
Bhatapukur	9257.14	7269.13	1907.73	1578.63	3782.77
Chatrapukur	12215.25	7332.62	2728.55	2465.85	2138.22
Komela pond	8525.26	6221.62	2216.46	2031.11	1974.05
Surjahi pond	8545.65	4221.81	1625.86	1247.09	1348.86
Lole pond	16823.24	14665.23	3869.58	3688.41	7107.24
Beel pukur	9288.84	6062.90	2097.15	1823.02	2142.73
Belpukur	12311.15	8157.93	2522.53	2191.82	3443.58
Total	218326.68	170967.43	46125.41	39633.72	85208.30

Available water for supplementary irrigation in the pond was found out 85208.30 m^3 which is only 39% of the total storage capacity of the ponds.

3.3 Evapotranspiration

Evapotranspiration data was collected from January, 2011 to December 2021 and their mean was determined. It showed that most evapotranspiration required was 135.17 mm in June and lowest requirement was 36.01 mm in December. Evapotranspiration depends on various factors such as temperature, humidity, wind speed, solar radiation etc. As temperature and humidity remain relatively higher from May to October, in that period evapotranspiration is also higher than the rest of the year. The mean monthly evapotranspiration is shown graphically in Figure 6.

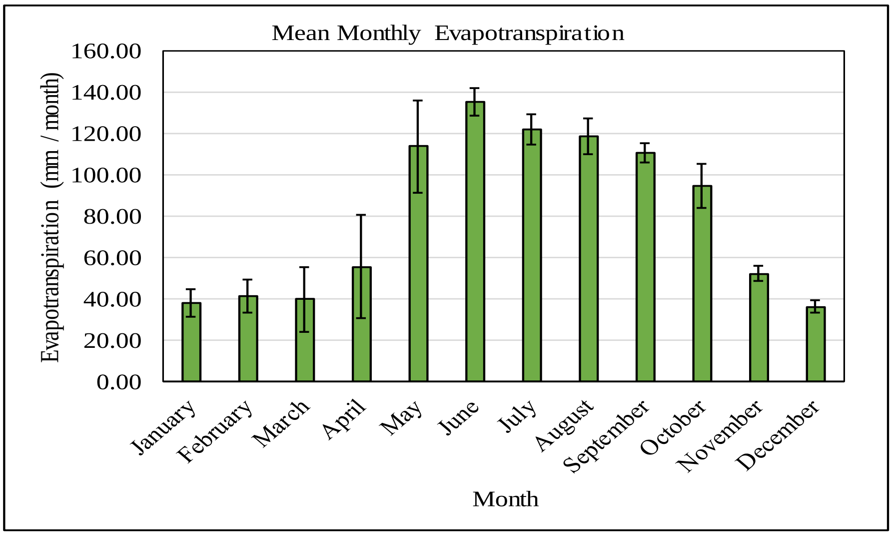

Figure 6: Mean monthly evapotranspiration from 2011 to 2021.

3.4 Crop Irrigation Requirement

From month May to October, effective rainfall exceeds the monthly evapotranspiration. So, there is no need for supplementary irrigation in these months. And the excess amount of runoff can be stored in the ponds for the purpose of use in the dry season. That is why the bars representing irrigation requirements for these months are at negative side of the graph. It is also seen that the maximum negative value is 105.44 mm in the month of July and the least excess value is only 1.77 mm in October (Figure 7). Supplementary irrigation required only from November to April. In November 44.00 mm of water required for supplementary irrigation which is maximum for this period and least irrigation required was 3.58 mm in April.

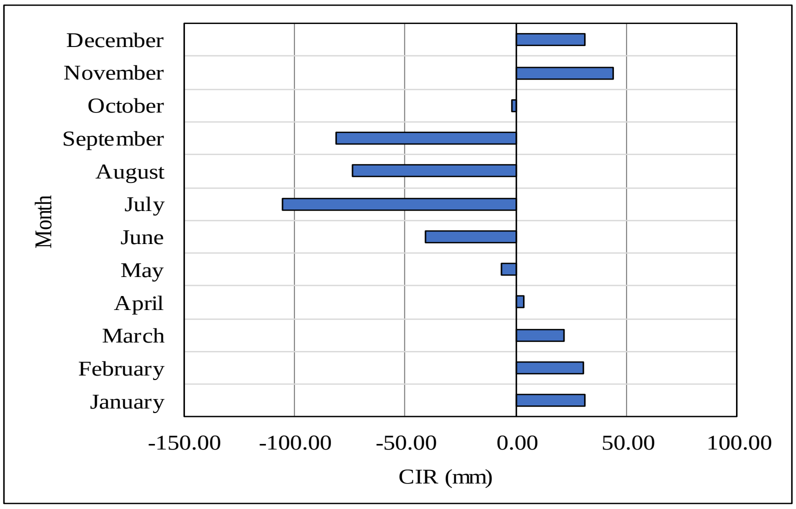

Figure 7: Monthly crop irrigation requirement

3.5 Culturable Command Area under Each Pond

Culturable command area for each pond is related to determination of the water required at the field. The more of the area a pond have, the more of the water will be required for irrigation purpose. Lole pond had the largest command area under it and the area was 195854.47 m^3. The command area is presented in Table 2.

Table 2: Culturable command area under each pond (Source: BMDA)

Pond name	Pond area (acres)	Culturable command area (m^2)
Durga vasa pond	1.12	89900.41
Dorga pond	1.10	88295.05
Jarsatin pond	1.55	124415.75
Natunpa pond	1.68	134850.62
Kadompukur	1.00	80268.23
Kodom pond	1.00	80268.23
Kismotsakoalpukur	1.29	103546.01
Mohobothpur pond	1.50	120402.34
Neem pukur	1.22	97927.24
School pond	1.29	103546.01
Alokchtro pond	1.09	87492.37
Singa pond	1.15	92308.46
Amra pond	1.26	101137.97
Domna pond	1.52	122007.70
Bhatapukur	1.97	158128.40
Chatrapukur	1.85	148496.22
Komela pond	1.14	91505.78
Surjahi pond	1.23	98729.92
Lole pond	2.44	195854.47
Beel pukur	1.02	81873.59
Belpukur	1.06	85084.32
Total		2286039.10

3.6 Water Required for Supplementary Irrigation

Total volume of water required in a month can be found by multiplying culturable command area (CCA) by crop irrigation requirement of that month. No irrigation required through May to October and total 370600.46 m^3 of water required for the rest of the year. The required irrigation water is presented in Table 3.

Table 3: Water requirement for irrigation throughout the year

Month	**CCA (m^2)**	**CIR (mm)**	**Total volume of water required (m^3)**
January	2286039.10	31.22	71378.72
February	2286039.10	30.32	69303.86
March	2286039.10	21.59	49364.37
April	2286039.10	3.58	8185.49
May	2286039.10	0.00	0.00
June	2286039.10	0.00	0.00
July	2286039.10	0.00	0.00
August	2286039.10	0.00	0.00
September	2286039.10	0.00	0.00
October	2286039.10	0.00	0.00
November	2286039.10	44.00	100580.36
December	2286039.10	31.40	71787.66
Total			370600.46

3.7 Ground Water Saving

The study shows that 85208.30 m^3 water is available in 21 ponds under consideration (Table 1) for irrigation which is 23% of the total irrigation requirement for the 2286039.10 m^2 culturable command area. However, there are total 2878 ponds in the study area. Considering all the ponds for supplementary irrigation the available water for supplementary irrigation is estimated in Table 4. It is found that with the total stored water in all ponds of the study area could save about 11.51%.

Table 4: Groundwater saving with supplementary irrigation

Total no. of pond	2878
Culturable area under the ponds (m^2)	313296215.60
Average depth of water required (m)	0.16
Total volume of water required (m^3)	50789910.34
Average volume of water stored in the pond (m^3)	2031.40
Total volume of water stored in the ponds (m^3)	5846383.46
% of ground water saving	11.51

3.8 Feasibility of Supplementary Irrigation

3.8.1 Net cost calculation

The average pond excavation cost of tk. 256858.42, purchasing and installation of pump and pipe costs of Tk. 15535 and Tk. 5000, respectively were collected from BMDA head office. Average command area under a DTW is 240000 m^2 and yearly water requirement for this area is 0.16 m. So, total water supplied by a deep tube well is around 38880 m^3. The average water stored at the ponds after all kinds of losses is 2031.40 m^3. And to meet the requirements of water supplied by a DTW, there would be 22 nos. of pond required. The cost regarding these 22 ponds is Tk. 6228847.

3.8.2 Net benefit calculation

The benefit comparison of pond water irrigation with respect to irrigation provided by DTWs in a year is shown in Table 5. Total benefit in a year is found to be of Tk. 4320000 while the net benefit is found to be of Tk. 135000 in a year considering irrigation cost and cultivation cost.

Table 5: Net benefit of supplementary irrigation

Crop production per hector (metric tons)	6
Average price per metric tons (Tk.)	30000
Benefit earns per hector (Tk.)	180000
Total benefit in a year (Tk.)	4320000
Total irrigation cost for pond per year (Tk.)	137955
Total cultivation cost of the command area (Tk.)	2832045
Net benefit in a year (Tk.)	1350000

3.8.3 Benefit cost ratio of present study

After considering 7% discount rate and period of 30 years, total cash inflows were found Tk. 35798143 and total cash outflow was found Tk.6228847. Hence the BCR was found 5.75 which is much greater than one. And from the concept of BCR, it could be said that the initiative to use rainwater instead of groundwater supplied by DTW will be economically feasible.

3.8.4 Net present value (NPV) and internal rate of return (IRR)

The economic analysis was also carried out by net present value method (NPV). After considering the discount rate and project period same as BCR method, the net present value was estimated to Tk. 27,634,852.00 which is much higher than the net cost associated with this initiative indicating the fact that it will be a profit-making decision. Internal rate of return (IRR) was found out 29% after considering a discount rate of 7% and period of 30 years.

3.8.5 Sensibility analysis based on various discount rates

The viability of the benefit-cost analysis is assessed at 5%, 10%, and 15% discount rates. The NPV values have always been positive, and the BCR values have always been more than one which indicates the project to be economical in terms of cost analysis and ground water saving. Table 6 shows the BCR and NPV values for 5%, 10% & 15% discount rate.

Table 6: BCR and NPV value for 5%, 10% & 15% discount rate

Parameters	Discount rate (%)		
	5	10	15
BCR	7.72	3.91	2.35
NPV (Tk)	39861547	16486094	7326840

The analysis shows that the proposed initiatives would be beneficial with BCR of 2.35 even considering discount rate of 15. Similar study at Tanore Upazilla under Barind tract shows the BCR of 2.07, NPV of BDT 24,619,316 and IRR of 25% (Bari, et al., 2023) while the present study on Godagari Upazila provides higher BCR and IRR.

4. CONCLUSIONS

Ponds have been used for a long time in the present study area under Godagari Upazila of Rajshahi district for domestic use and small scale irrigation in some cases. Re excavation of the ponds accelerates during last some period of time. It could reduce the groundwater uses to some extent and increase dependency on surface water. From the present study it could be said that more groundwater could be possible to save by storing rainwater in all abundant ponds by re-excavation. Furthermore, water losses are very high in the study area which is under Brind tract, water stressed dry area. By applying effective techniques losses of water could be reduced which lead to more storage of pond water and there will be more water to use in dry seasons. From the present study it was found that to reduce the dependency on groundwater, use of surface runoff can be a good alternative. And it is economically feasible too. More ponds should be excavated and proper techniques to reduce the evaporation and seepage loss should also be considered. If this can be possible, there will be more scope to reduce the use of groundwater and use of rainwater will be more economical.

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