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Feasibility Study of Supplementary Irrigation with Pond Water in Tanore Upazilla under Barind Tract

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Abstract

The Barind tract is a water-scarce region in the northwest zone of Bangladesh. The study area, Tanore Upazila, situated under high Barind tract where groundwater is only the main source of irrigation water. The uncontrolled installation of deep tube wells for irrigation in this area, by both the private and government sector, aggravated the groundwater situation. This over exploitation of groundwater causes the continual depletion of water table. The use of surface water as an alternative source of irrigation would be a viable solution to tackle this problem. A pond is a small water body that stores rainwater from surface runoff can be used for supplementary irrigation source. Therefore, the feasibility of supplementary irrigation with rainwater stored in ponds was investigated in terms of benefit cost ratio (BCR), net present value (NPV), and internal rate of return (IRR). The study showed that about 14.6% of required irrigation can be provided with pond water, which indicates 85% saving of groundwater. The economic and financial analyses showed the BCR value two, NPV > 0, and IRR equal to 25% for the current initiative. By considering the groundwater conservation and economic analysis, it is possible to conclude that supplementing irrigation in the study region with pond water is feasible.

Keywords:*Barind tract, supplementary irrigation, benefit cost ratio, net present value, internal rate of return*.

1 Introduction

The drought prone Barind region of Bangladesh has a typical less annual rainfall ranges from 1,250 to 2,000 mm with an average of 1418 mm (Chowdhury, et al., 2016), whereas the national average is 2500 mm and high temperature ranges from 4ºC to 44ºC. Between June and October, nearly 80% of precipitation occurs. Gradual decreasing trend in precipitation is prevailing in the Barind tract that causes the reduction of availability of sufficient water (Hossain, et al., 2021; Hossain, et al., 2020; Bari, et al., 2019; Hossain, et al., 2019a) Due to a lack of surface water, groundwater-based irrigation is widely used to cultivate high-yield rice during the dry season (Scott and Sharma, 2009). In these arid regions, rice cultivation specially for Boro rice is extremely difficult due to the farmers' reliance on groundwater during the dry season. Groundwater provides about 45 to 70% of irrigation water (Lall, et al., 2020). Approximately 80% of the agricultural land is irrigated with groundwater, and groundwater scarcity increased by 42% annually in northwest Bangladesh (Shahid and Hazarika, 2010). The rate of groundwater withdrawal for irrigation and drinking is gradually increasing in this region. The overexploitation of groundwater for irrigation is considered one of the main causes of water table depletion (Hossain, et al., 2022; Bari, et al., 2021; Hossain, et al., 2020; Hossain, et al., 2019b). As a result, the groundwater level in this region is decreasing gradually due to an increasing demand for irrigation water (Rahman and Mahbub, 2012).

The Barind Multipurpose Development Authority (BMDA) has successfully re-excavated 3,098 ponds of which 174 ponds are in Tanore upazila. Furthermore, approximately 715 additional abandoned ponds and 10 large, enclosed water bodies are available in the study area. The available water in these huge water bodies might create an opportunity for supplementary irrigation that can save the groundwater abstraction as well as reduce the groundwater depletion. Therefore, the aim of this study is to assess the feasibility of supplementary irrigation with pond water.

2 Methodology

The feasibility of supplementary irrigation with pond water was assessed in terms of healthy internal rates of return, positive net present values, and benefit–cost ratios greater than one. The methodologies were followed in this study are briefly described in the following sections.

2.1 Study Area

Tanore upazila in Rajshahi district under Barind tract is considered as study area having population of 173495 within 2,958 km^2 (29,580 ha) area. It is situated within latitude and longitude of 24°29′ N to 24°43′ N and 88°24′ E to 88°38′ E, respectively. The total cultivable land area is approximately 22,656 km^2 (22,656 ha). Nearly 43% of the population is engaged in agricultural activities. The cropping intensity in Tanore is relatively high at approximately 26.2 percent.

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 were 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 Tanore 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 A 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). Minmum 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. There are different methods for economic and financial evaluation of a project. 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).

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

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).

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

Where, R_t = 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.

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

Where, IRR= Internal rate of return, C_t = Total cash flow present value, C_o = Total initial investment and T= time period.

3 Results and Discussion

There are both international and national-level studies. However, micro scale or localized studies are uncommon. Because of rainfall amount and crop water requirements for the same crop vary from region to region, regional studies are more important. The study was conducted to determine the feasibility of pond water contribution to the total demand for rice production in Tanore upazila, Rajshahi, Bangladesh.

3.1 Available pond water for supplementary irrigation

The storage capacity of each pond, annual runoff water under each pond's catchment, surplus runoff water, volume of water through evaporation and percolation as well as water requirement for fish culture are presented in Table 1. There are 30 ponds in the study area and their total storage capacity is 2,34,282 m^3. The available total runoff water towards the ponds is 294663.5 m^3. The storage water of ponds is equal to the capacity of the ponds because of capacity is less than the runoff water. The annual total available water in the ponds considering the evaporation loss, percolation loss and minimum water requirement for the fish culture is 61797.9 m^3. The analysis shows that storage water in Dighi, Baropukur and Billy ponds are negative means that the storage water is not sufficient to fulfill the demand of fish culture as well as losses. Therefore, storage water of all ponds cannot be used for supplementary irrigation.

3.2 Irrigation requirement

The consumptive irrigation requirements were estimated by subtracting the effective rainfalls from the consumptive uses. Thirty years rainfalls from 1991 to 2020 were considered for determining the effective rainfalls. The yearly consumptive irrigation requirements are presented in Figure 2. The analysis shows that the CIR is negative during June to September due to the surplus amount of precipitation compared to consumptive usage. In contrast, the CIR is positive with average of 17.13 cm for eight months from February to May. The analysis indicates that land need to be irrigated for eight months of the year. The remaining four months' consumption requirements can be met by rainfall alone.

The net irrigation requirement (NIR) is defined as the amount of water required to meet the evapotranspiration needs as well as other needs while field irrigation requirement (FIR) is the amount of water required to meet the NIR and amount of water lost as surface runoff and deep percolation. It can be expressed as FIR = NIR (CIR and other losses) + surface runoff losses + deep percolation losses. The amount of irrigation water required is estimated based on the FIR for the total cultivable land of 248.35 ha in the study area and it is presented in Table 2.

Table 1: Available pond water for supplementary irrigation

Pond Name	Storage capacity, m^3 (1)	Annual Runoff, m^3 (2)	Surplus water, m^3 (3=2-1)	Evaporation loss, m^3 (4)	Percolation loss, m^3 (5)	Fisheries requirement, m^3 (6)	Available water for irrigation, m^3 (7=1-4-5-6)
Shimul	10769.4	12480.0	1710.6	2200.0	825.7	2950.7	4793.0
Mathurakuri	7443.8	9397.7	1953.9	1301.4	415.3	1484.0	4243.1
Chatra	7699.3	9720.3	2021.0	1354.0	557.3	1991.4	3796.6
Ekannopur	6388.0	8064.8	1676.8	1953.3	826.8	2954.5	653.5
Panapukur	7348.4	9277.3	1928.9	2024.3	751.6	2685.9	1886.6
PiyajaChaci	4610.3	5820.5	1210.2	863.9	260.3	930.1	2556.0
Ahar	4366.1	5512.2	1146.1	1123.3	400.8	1432.2	1409.8
Damkuri	4011.5	5064.5	1053.0	1173.4	438.0	1565.3	834.8
Sidankuri	5422.7	6846.1	1423.4	1150.1	356.6	1274.3	2641.7
Paikerhat	8310.5	10491.9	2181.4	1702.5	622.7	2225.4	3759.9
Phatahala	4265.7	5385.5	1119.7	1184.6	428.8	1532.2	1120.2
Dighi	17881.8	22575.6	4693.8	5967.0	2612.7	9336.7	-34.7
Baropukur	6806.9	8593.6	1786.8	2440.0	1077.0	3848.9	-559.0
Pipra	24223.6	30582.1	6358.5	4604.1	1909.7	6824.4	10885.4
Saralapukur	19913.7	25140.9	5227.2	4832.6	2316.1	8276.6	4488.4
Kathihara	3534.3	4462.0	927.73	628.0	167.5	598.6	2140.1
Panapukur	5428.5	6853.4	1424.9	1409.0	480.4	1716.6	1822.5
AikaraKuri	3444.5	4348.7	904.16	1017.5	355.3	1269.6	802.2
Jhaljhala	6074.8	7669.5	1594.6	1541.5	633.6	2264.3	1635.4
Billy	5483.3	6922.6	1439.3	3602.3	1446.3	5168.6	-4734.0
Madhyapukur	7099.6	8963.2	1863.6	2129.6	934.4	3339.0	696.5
Piprakalna	5126.5	6472.1	1345.7	1237.3	471.7	1685.7	1731.7
Purapukur	4558.6	5755.2	1196.6	1245.2	478.7	1710.6	1124.0
Kharpukur	14397.0	18176.1	3779.1	4599.3	2040.5	7291.8	465.5
Singrapukur	4203.1	5306.4	1103.3	1109.0	383.8	1371.6	1338.7
Talpukur	7062.5	8916.4	1853.9	1758.9	606.6	2167.7	2529.3
Kalitala	4212.5	5318.3	1105.8	1110.4	422.6	1510.1	1169.4
Madrasa	11945.0	15080.4	3135.5	1995.1	758.6	2711.0	6480.3
Taitakuri	4497.2	5677.7	1180.5	1258.9	536.1	1915.9	786.2
Nalpukur	7753.4	9788.6	2035.2	2231.1	915.6	3271.9	1334.8
Total	234282.3	294663.5	60747.6	60747.6	24431.1	87305.8	67125.6

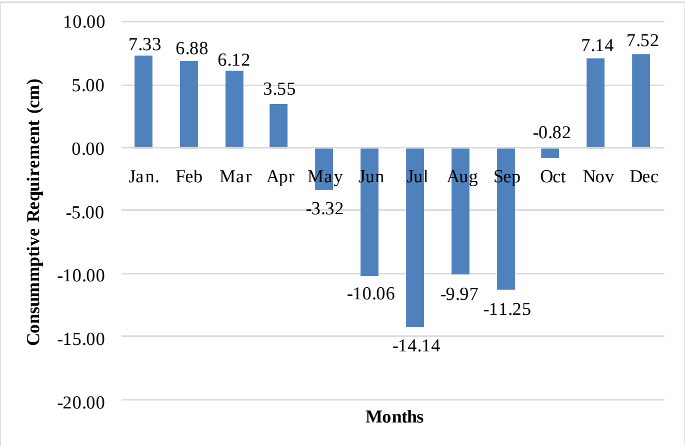

Figure 2: Consumptive irrigation requirement

The total demand of irrigation water is 460166 m^3 while the available water for irrigation 67125.6 m^3, which is 14.6% of demand. Therefore, same quantity of deep well irrigation and groundwater can be saved by supplementary irrigation with pond.

Table 2: Annual requirements of irrigation water

Months	Culturable command area (m^2)	FIR (cm)	Total volume of water required (m^3)
January	2483491.92	10.32	256296.37
February	2483491.92	13.99	34744.05
March	2483491.92	15.83	39313.68
April	2483491.92	14.47	35936.13
May	2483491.92	7.99	19853.03
June	2483491.92	0.00	0.00
July	2483491.92	0.00	0.00
August	2483491.92	0.00	0.00
September	2483491.92	0.00	0.00
October	2483491.92	7.09	17598.02
November	2483491.92	12.86	31937.71
December	2483491.92	9.86	24487.23
	Total		460166.22

3.3 Economic and financial feasibility

Costing of deep tube well irrigation and to rain-fed pond water irrigation were considered for economic and financial analysis. The benefits of crop production with pond water irrigation were compared with deep tube well irrigation. The net returns of various crops were computed by subtracting the cost of all variable inputs, such as irrigation, seed, fertilizer, chemicals, and labor, from the gross returns. In the study, the installation cost of the DTW, the cost of the submersible pump, labor, boring, pipe and transportation costs, power connection and appliance costs, and the cost of the house for the submersible pump were regarded as the project's inflow. The required information was collected from BMDA office. Two dynamic economic indices, financial net present value and financial internal rate of return (IRR) were used to analyze the costs and benefits arising from ponds. The benefit cost ratio was also determined to evaluate the economic feasibility. The analyses are shown in Table 3.

Table 3: Economic and financial analyses for pond water irrigation

Periods (Years)	Cash flow (Tk)	PV factor	Amount (Tk)
0	-24621224.0	1	-24621224
1	17590284.3	0.934579439	16439518
2	3220856.6	0.873438728	2813221
3	3220856.6	0.816297877	2629178
4	3220856.6	0.762895212	2457176
5	3220856.6	0.712986179	2296426
6	3220856.6	0.666342224	2146193
7	3220856.6	0.622749742	2005788
8	3220856.6	0.582009105	1874568
9	3220856.6	0.543933743	1751933
10	3220856.6	0.508349292	1637320
11	3220856.6	0.475092796	1530206
12	3220856.6	0.444011959	1430099
13	3220856.6	0.414964448	1336541
14	3220856.6	0.387817241	1249104
15	3220856.6	0.36244602	1167387
16	3220856.6	0.338734598	1091016
17	3220856.6	0.31657439	1019641
18	3220856.6	0.295863916	952935
19	3220856.6	0.276508333	890594
20	3220856.6	0.258419003	832331
21	3220856.6	0.241513087	777879
22	3220856.6	0.225713165	726990
23	3220856.6	0.210946883	679430
24	3220856.6	0.19714662	634981
25	3220856.6	0.184249178	593440
NPV	24,619,316.00	Total cash inflow	50963895
IRR	25%	Total cash outflow	24621224
		BCR	2.07

The analyses show that the benefit-cost ratio (BCR) is more than two which indicates the pond water irrigation is economically viable while net present value (NPV) and internal rate of return (IRR) are BDT 24,619,316and 25% that depict the proposed supplementary irrigation is financially feasible.

4 Conclusion

This study demonstrates the role of effective rainfall and the prospective contribution of RWH in derelict pond as a supplemental irrigation in Tanore, Rajshahi. The irrigation is not required from June to September because the amount of precipitation exceeds the quantity of water required for consumption irrigation. The available pond water of 67125.6 m^3 can be supplemented for irrigation, which is 14.6% of irrigation demand. At the same time, it will reduce the stress on groundwater irrigation. Moreover, the supplementary irrigation with pond water is economically and financially feasible with BCR of 2.07, NPV of BDT 24,619,316and IRR of 25%. Therefore, the supplementary irrigation with rain-fed pond water would be implemented in the Tanore upazila, Rajshahi under Barind tract.

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