Proceedings of International Conference on Planning, Architecture and Civil Engineering, 12 - 14October 2023, Rajshahi University of Engineering & Technology, Rajshahi, Bangladesh

Paper ID: CE 0362

Potentiality of Supplementary Irrigation with Existing Small Water Bodies in Patnitala and Sapahar Upazila of Naogaon District

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Abstract

Patnitala and Sapahar upazilas under Naogaon district are drought prone Barind tract situated in the northwest part of Bangladesh. The agriculture is the major economy of this zone. The crop production is basically dependent on irrigation with groundwater. The excessive extraction of groundwater for the purpose of irrigation in this region headed to a depletion of groundwater resource. However, the existing small water bodies like ponds capture rainwater through surface runoff during the monsoon might be a potential source of supplementary irrigation. The available information of existing small water bodies like ponds of the study area was collected from Barind Multi-Purpose Development Authority (BMDA). The storage capacities of all ponds in the study area were calculated and total storage water was estimated by runoff calculation. The available pond water for supplementary irrigation was determined by subtracting the losses (i.e., evaporation loss and percolation loss) and water requirement for fish culture. The study shows that annually average 11.13% of total irrigation water is possible to accomplish with the available pond water. However, about 38% irrigation would be possible with total rainwater by capturing in available government dead ponds with necessary rehabilitation. Furthermore, the possible supplementary irrigation from small water bodies will reduce the same amount of groundwater extraction and save groundwater as well. Therefore, storage water of existing small water bodies in the study area has a significant potentiality for the supplementary irrigation.

Keywords:*Barind tract; small water bodies; supplementary irrigation; potentiality; groundwater saving.*

1 Introduction

The Barind tract is completely distinct from the rest of the country and located in the country's driest region, which is a drought-prone and water-stressed area (BMDA, 2018). Most of the terrain consists of undulating terraces. Temperatures in the region ranges from 8 ºC to 44 ºC (Ahmeduzzaman, et al., 2012), and receives a lower amount of precipitation in contrast to other parts of the country. The annual rainfall varies from 1250 mm to 2000 mm. Almost 80% of the yearly rainfall occurs between June and October (IWM, 2012). The growth of this region's economy as a whole is significantly impacted by the contributions made by the agricultural sector. During the dry season, approximately 42% of High Barind tract (HBT) faces groundwater scarcity for Boro rice farming (Shahid and Hazarika, 2010). Overexploitation for irrigation has triggered groundwater levels to fall to the point where they are not fully replenished during the recharge season.

The availability of irrigation in Barind tract has changed its agriculture, but excessive extraction is causing the groundwater level to decline across the area. Due to the absence of seasonal flooding, groundwater depletion is severe in the study area. For this reason, experts suggest for alternative water sources for irrigation purposes (Rahman and Mahbub, 2012). Therefore, it is necessary to find out a reliable alternative source of irrigation. The rainwater augmentation in the ponds might have the possibility of becoming a reliable source of irrigation water. Therefore, the potentiality of supplementary irrigation with pond water instead of groundwater was analyzed in the present study.

2 Methodology

2.1 Study Area

Patnitala and Sapahar Upazila of Naogaon district under Barind tract are considered as study area for this study as water stressed area. Patnitala Upazila (Naogaon district) has a land area of 382.39 km^2 and is located between 24°59' and 25°12' north latitudes and 88°35' and 88°55' east longitudes. The total population of this upazila is 209440 people. Agriculture is the most important source of income (80.24%). Patnitala upazila has an annual rainfall of around 1310 mm. The annual average temperature ranges between 15°C and 37°C. The average annual humidity is around 62% (BBS, 2020). Sapahar Upazila (Naogaon district) is situated between 25°01' and 25°13' north latitudes and 88°26' and 88°38' east longitudes with a total area of 244,49 km^2. This upazila has a total population of 1,43,853 persons. Agriculture is also the primary source of income at 79.03% like Patnitala upazila. The average annual rainfall in Sapahar upazila is about 1,298 millimeters. The annual average temperature ranges between 15°C to 38°C. The average yearly humidity is approximately 61% (BBS, 2020).

2.2 Data collection and analysis

The intensity of the rainfall in the catchment area determines how much runoff goes toward a pond. The crops that are grown in this region require irrigation, which is influenced by rainfall patterns. The climate engine app was used to gather monthly rainfall data from 1992 to 2021 in order to understand the quantity and pattern of rainfall. The Google Earth Pro was utilized in order to calculate the catchment area under the ponds located in this area of study from the elevation profile. The coordinates of each pond were obtained from the office of the BMDA in Rajshahi. The Rational method was used to calculate runoff from drainage areas toward the pond (eq. 1).

$$Q = 2.778CIA \quad (1)$$

where, C = runoff coefficient, I = precipitation rate (cm/hour), A = catchment area (km^2,) Q = quantity of runoff (m^3). In this study area, most of the area cultivated is regular land and having slope less than 5%. The soil is found as clay or silty loam (Ali, et al., 2019). So, runoff coefficient C is taken as 0.6 for the determination of runoff volume.

The BMDA conducted a topographical survey for the calculation of storage capacity of each pond. The data required for the calculation of storage capacity was collected from BMDA. Storage capacity of each pond was calculated by using trapezoidal rule (eq. 2). Storage capacity is equal to the volume of pond.

$$V_p = \frac{d_c}{2}(A_f + A_l) + 2\sum A_o \quad (2)$$

Where, V_p = volume of pond, d_c = common distance, A_f = area of the first section, A_l = area of the last section, A_o= area of other sections and area of section = average length × average width.

2.3 Losses of water

The rate of evaporation was measured with a "Class A Evaporation Pan". This standard evaporation pan is made of stainless steel and the dimensions of a "class A" evaporation pan are 54 mm (10 inches) height and 206 mm (47.5 inches) in diameter. The evaporation pan was placed on the leveled ground at the pond side in a grassy area, far from bushes, trees, and other obstacles that would obstruct a natural air flow around the pan, symbolizing open water in a broad expanse of land. The pan was filled with water at a particular depth and loss of water was measured by adding required volume of water to reach the required depth at every 24 hours. The loss of water is expressed in mm/day and the pond evaporation rate was calculated by multiplying the pan evaporation rate with pan coefficient (K). The pan coefficient was considered as 0.8 based on the local wind velocity of 1.20 ms^{-1} to 2.90 ms^{-1}, fetch of 1m from the pond, and relative humidity from 59% to 81%.

The single-ring infiltrometer of 300 mm diameter and 500 mm height was chosen for this investigation. The infiltrometer was inserted 150 mm into the soil within an excavated pit. The infiltrometer was filled with water and percolation of water was measured and recorded at intervals of 15 minutes for the first hour, 30 minutes for the second hour, and 60 minutes for the remaining portion of a period of approximately 24 hours.

2.4 Water Requirement of Crops

Blaney and Criddle (1950) 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.

3 Result and Discussion

3.1 Trend of Annual Rainfall

The annual precipitation varies greatly in the study area and it varies from 1125 mm to 1871 mm in Patnitala upazila and from 1122 mm to 1820 mm in Sapahar upazila (Figure 1). The alerming sign is thedeclining trend of annual rainfall. The rainfall declines at the rates of 3.25 mm/year and 2.56 mm/year in Patnitala upazila and Sapahar upazila, respectively. Similar declining trends were also observed in the other parts of the Barind tract (Hossain, et al., 2022; Bari, et al., 2021; Hossain, et al., 2021; Hossain, et al., 2020; Hossain, et al., 2019a; Hossain, et al., 2019b)

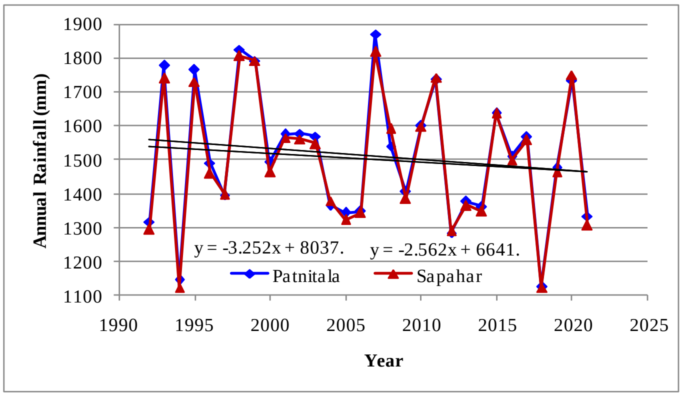

Figure 1: Annual rainfall trend in the study area

3.2 Storage and Surplus Water

A total of 13 ponds among which six ponds in Patnitala and seven ponds in Sapahar upazila were taken into consideration for this study. Catchment Area varies from 2.27Acres to 16.5 acres. Maximum catchment area found for Tatoir Dighi of 16.5 acres and minimum for Now Pukur 2.27 acres. Storage capacity of the ponds varies between 3775.02 m^3 to 8013.95 m^3 (Table 1). The maximum capacity is found at Tatehar pond located at Dibor union of Patnitala upazila and minimum capacity found at Now Pukur located at Tilna union of Sapahar upazila. There is one Dighi (Big ponds) in the study area whose storage capacity is about 29979.18 m^3.

The size of the catchment area, the amount of rainfall, and the runoff coefficient are the three factors that determine how much water flows into a pond after it rains. As the catchment area is relatively small in this case, the intensity of the rainfall is nearly identical. The majority of the land beneath the catchment area is cultivable flat land and the runoff coefficient is also almost identical. The volume of runoff toward the ponds in a year varies between 8524 m^3 to 60886 m^3. The results show that the total storage capacity runoff volume and volume of surplus water are about 96053 m^3, 211732 m^3 and 115679 m^3, respectively. It is observed that the storage capacities of the ponds are much less than the volume of runoff water towards the ponds. As a result huge amount of rainwater is not storing in the ponds and wasting as a surface runoff. The surplus water of each catchment area varies from 0.8 to 2.6 times of storage capacities of the ponds. Therefore, there is an opportunity to increase the storage capacity to utilize the available rainwater for supplementary irrigation and reducing the stress over the groundwater.

3.3 Water Losses and Available Water

The loss of water due to evaporation is greater if the top surface area of a pond is larger, but the loss due to percolation is greater if the bottom surface area of a pond is larger. The average evaporation rate was found to be 2.13 mm/day. The average percolation rate is found to be 1.13 mm/day. Evaporation losses, percolation losses, the total losses and available water of different ponds in a year are shown in Figure 1. The results show that the total losses of water vary from 1692 m^3 to 15525 m^3 which is about 40% to 60% of the storage water in different ponds depending on the size of the ponds. Furthermore, total available water is 47609 m^3 in total 13 ponds while storage water is 96053 m^3 which indicates that about 50% storage water is available for necessary use.

Table 1: Location and Co-ordinate of different ponds provided by BMDA

Pond Name	Co-ordinate	Runoff Volume (m^3)	Storage Capacity (m^3)	Surplus Water (m^3)
Choto Dighi Dibor, Patnitala	N:25° 7'14.51" E:88°36'50.44"	24288.58	8013.95	16274.63
Tatehar Pond Dibor, Patnitala	N:25° 7'22.07" E:88°36'45.81"	19564.77	5375.28	14189.49
Damapukur Dibor, Patnitala	N:25° 6'11.75" E:88°38'19.10"	11642.15	5659.50	5982.66
Paddapukur Dibor, Patnitala	N:25° 5'54.46" E:88°37'12.96"	11790.93	6394.36	5396.57
Per Pukur Dibor, Patnitala	N:25° 5'58.81" E:88°37'15.60"	10414.70	4595.50	5819.21
Tael Pukur Dibor, Patnitala	N:25° 5'51.39" E:88°38'3.92"	10228.73	4589.55	5639.18
Jampukur Aihai, Sapahar	N:25° 9'29.10" E:88°29'38.87	9409.69	5017.14	4392.55
BaroPukur Aihai, Sapahar	N:25°11'11.93" E:88°29'54.95"	19815.70	9150.78	10664.92
MithaPukur Shironti, Sapahar	N:25° 9'8.25" E:88°33'1.03"	8524.07	4364.33	4159.74
Tatoir Dighi Shironti, Sapahar	N:25° 8'53.96" E:88°32'58.20"	60886.23	29979.18	30907.05
DodonPukur Shironti, Sapahar	N:25° 9'23.40" E:88°33'36.92"	8007.46	4531.86	3475.60
GholaPukur Patari, Sapahar	N:25° 8'34.08" E:88°29'4.92"	8782.38	4606.65	4175.73
Now Pukur Tilna, Sapahar	N:25° 4'11.24" E:88°36'7.27"	8376.47	3775.02	4601.45
Total		2,11,731.87	96,053.10	1,15,678.78

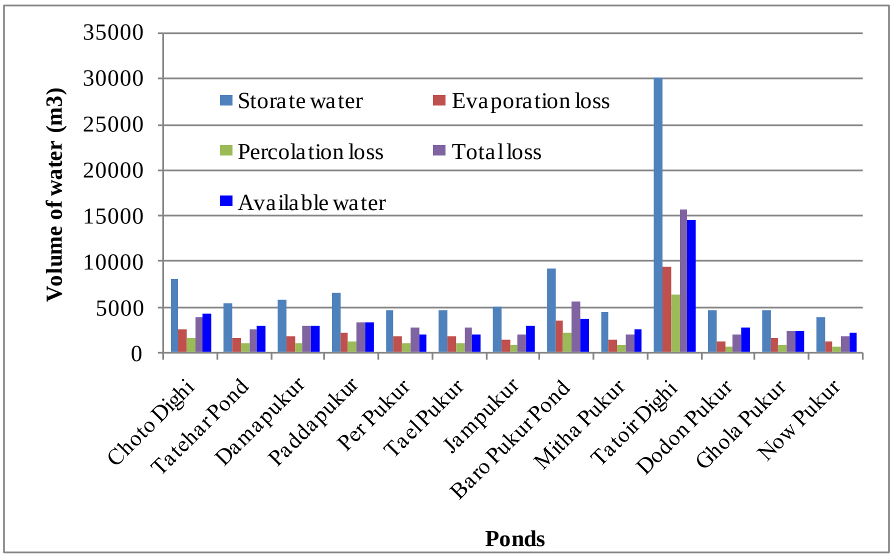

Figure 1: The losses and available water in the ponds

3.4 Water Requirement for Crops in Different Months

Water requirement of crops is not same all over the year. In the study area maximum consumptive use of water is required during May to July. Consumptive irrigation requirement (CIR) is higher in January, February, March, November and December. From June to October effective rainfall is more than Actual Evapotranspiration. So, in these months CIR is negative. Amount of consumptive use, effective rainfall and CIR for different months are shown in Figure 2.

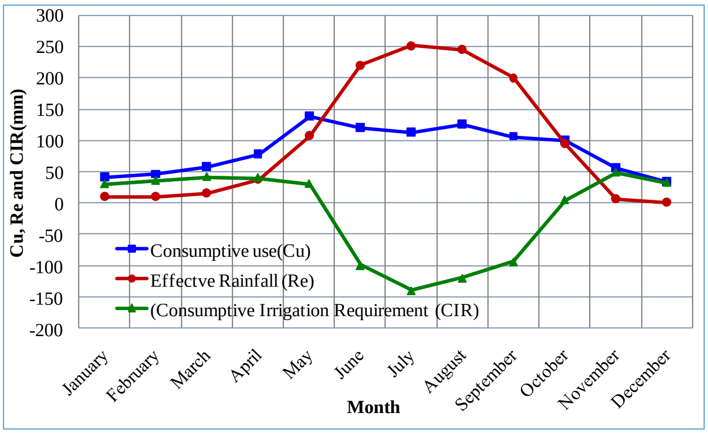

Figure 2: The consumptive irrigation requirements based on consumptive use and effective rainfall

3.5 Cultivable Command Area and Total Volume of Water Required

For different crops, water requirements are different. The major crops in the study area are rice, wheat, mango, potato, and different types of fruits and vegetables. The annual volume of water needed to fulfill the water requirements of these major crops is calculated by adding the monthly CIR values for the year. The calculated volumes of water required for the command area under different ponds are shown in Table 2. Cultivable command area under each pond was collected from BMDA.

Table 2: Irrigation requirement and availability under different ponds

Pond Name	Command Area (m^2)	Annual Water Requirement (m^3)	Available Irrigation Water (m^3)	Irrigation Deficiency (m^3)
Choto Dighi	132741.6	35442.01	4135.205	31306.8
Tatehar Pond	98746.8	26365.4	2848.457	23516.94
Damapukur	83368.2	22259.31	2889.66	19369.65
Paddapukur	97128	25933.18	3210.306	22722.87
Per Pukur	93890.4	25068.74	1940.635	23128.1
Tael Pukur	118981.8	31768.14	1918.912	29849.23
Jampukur	72036.6	19233.77	3079.461	16154.31
BaroPukur Pond	130313.4	34793.68	3624.954	31168.73
MithaPukur	75274.2	20098.21	2436.76	17661.45
Tatoir Dighi	469452	125343.68	14454.25	110889.4
DodonPukur	61514.4	16424.34	2724.675	13699.67
GholaPukur	83368.2	22259.31	2263.186	19996.12
Now Pukur	84177.6	22475.42	2082.911	20392.51
Total	1600993.2	427465.19	47609.37	379855.8

The results show that the total annual irrigation requirement is about 427465 m^3 for 160 ha cultivable command area while total irrigation can be provided of 47609 m^3 with pond water which is 11.13% of total demand. However, total surplus rainwater that was not stored in the pond is 115678.78m^3 (Table 1). This additional rainwater is about 27% of the total irrigation demand. It means that about 38% irrigation can be supplemented with rainwater in the study area. At the same time same amount of groundwater can be possible to save by supplementary irrigation.

4 Conclusion

The rainfall trend analysis showed that annual average rainfall is declining same as other parts of the Barind tract. The amount of water lost from the ponds because of evaporation and seepage is about 50% of the total storage of rainwater. Available water in the existing ponds is not sufficient to meet the consumptive irrigation requirement in the dry season. It will fulfill about 11.13% of the total irrigation requirement of the study area. The runoff towards the ponds is more than the storage capacity of the ponds. Annually about 115678.78m^3 of rainwater is not possible to capture in the existing ponds which could fulfill additional 27% of the total irrigation demand. It reveals that about 38% irrigation can be supplemented with rainwater and at the same time same amount of groundwater can be saved in the study area. Therefore, the dead ponds under government jurisdiction in the study area should be rehabilitated for capturing the total possible rainwater.

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