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USABLE WATER ASSESSMENT FOR NORTH-EASTERN PART OF BANGLADESH: A CASE STUDY

E. Shaik[1*] and M. T. Islam[1]

Abstract

The agro-based north-eastern haor region of Bangladesh is very important for crop production and food security of the country. The irrigated crop of dry season faces useable water scarcity. So usable water assessment during the dry season is very important for agro-based Haor area to know the extent of necessary surface water development measures for the study area. At the same time, Haor area is engulfed with various water-related problems and constraints viz. pre-monsoon flash flood and seasonal flood due to excess rainfall, climatic variability, river capacity reduction; water logging due to unplanned road construction and canal or creek filled up, disruption of hydraulic connectivity between Haor and river and dry seasonal water scarcity. The study intends to explore the dry season water security which one of the major concerns for the development of agro-based north-eastern Haor region of Bangladesh. The distinct water scenarios like status of usable water in terms of stream flow, static flow, dependable rainfall, and usable groundwater during dry season is estimated which necessitate assessment of crop water demand and supply requirement to know the spatio-temporal scenario of water whether surplus or deficit is important for regional policy planning and water management of the study area.

Keywords: *rainfall, evapotranspiration, crop production, crop water demand, usable water.*

Introduction

The unique hydro-ecological characteristics of the study area are large bowl-shaped floodplain depressions which cover about 2372.67 sq. km within 19,998 sq. km of total area and accommodating about1.99 million people within 19.37 million (BHWDB, 2012; Bevanger *et al.,* 2001; IUCN, 2002). There are 373 Haor located in the north-eastern part including the study area of Sunamganj, Netrakona, and Kishoreganj (Hossain, 2013). These 373 Haors cover an area of about 859,000 ha which is around 43% of the total area of the Haor districts and in the study purposes 1527.16 sq. km is considered that is actually the agro-based area (BHWDB, 2012). It is a mosaic of wetland habitats including rivers, streams, canals, large areas of seasonally flooded cultivated plains and beels. It is difficult to foresee the country's overall progress without the development of the Haor region as it covers a major part of the country and population which deserves special development initiatives. Both BRRI dhan 28 and 29 were being the widely adopted rice varieties. On an average, about 33% of the haor areas were under mechanized irrigation, but in Kishoregonj, the coverage of mechanized irrigation was 87% that helped increasing cropping intensity. In Kishoregonj and Habigonj, nearly 94 and 87% areas were devoted to Modern Variety (MV) Boro rice production. Alam *et al.* (2010) studied on Crop Production in the Haor Areas of Bangladesh; assess the land utilization status, delineate the productivity and profitability of growing modern rice, evaluate the existing cropping patterns and depicts the prospect of possible cropping patterns.

Khan *et al.* (2012) conducted a study on the Impacts of Flood on Crop Production in Haor Areas of Two Upazillas in Kishoregonj. Haor is a basin-like structure where water remains either stagnant or in flash flooding condition during the months of June to November. In Bangladesh, Haor areas are covered by Boro rice and produce a large amount. Severe flood damage the boro crop, so that the study was conducted to know the land use pattern and impact of the flood on boro rice production. Flood control measures would be taken to prevent a huge loss of boro rice. Hossain *et al.* (2017) also conducted an experiment about the impact of Flash Flood on Agriculture Land in Tanguar Haor Basin. The most diversified ecosystem Tanguar haor, is not only ecologically but also socio-economic important for supporting livelihood to around 70,000 people. Geographical location has made it vulnerable to adverse impacts by a flash flood in almost every year.

The future challenges in the context of climate change are also a major concern for the sustainable development of the region. Haor resources have been broadly grouped into three categories: human, economic and natural resources based on an understanding of the possible size, composition, resource management and growth potentials for resources in the area

[1] Water Resources Planning Organization, WARPO Bhaban, 72 Green Road, Dhaka-1215.
*Corresponding Author (E-mail:ershad.ju@gmail.com)

(BHWDB, 2012). The physiography of the study area is Old Brahmaputra Floodplain, Sylhet Depression and Meghalaya Foothills within eleven physiographic units. The climate of the study area is classified as tropical. The summer has a good deal of rainfall, while the winter has very little. The mean temperature during the summer months remains within 23°C to 30°C. April and May are the hottest months. Over the rest of the country, it ranges from 41°C to 43°C. The post-monsoon months of October and November are transition months from summer to winter and it is quite hot in October (Khatun *et.al.* 2016). The average annual rainfall ranges from 2222 mm to 4961 mm whereas maximum 1337 mm rainfall in Bishwamvarpur, Sunamganj in July. The major rivers of these districts are Bhatta, Baulai, Dhanu, Dahuka, Derai, Ghorauta, Kalni, Kangsha, Meghna, Nawa, Old Brahmaputra and Surma (WARPO, 2016). The usable water in the dry season is not sufficient to meet the demand despite available river and perennial of water bodies. Dey *et al.* (2017) studied on the recent flash flood'17 in the north-east region which was triggered by heavy rainfall has breached parts of embankments and resulted in huge loss of assets and income of Haor dwellers. The aim of the study was to investigate the impact of flash flood'17 in different sectors, such as agricultural production, livelihood including food security, education system, social and gender vulnerability, water, sanitation and health, and economic groups. Nowreen *et al.* (2015) also monitored the Haors as large, round-shaped floodplain depressions located in the North-Eastern region of Bangladesh. Extreme events such as heavy rainfall routinely affect the Haor basin with flash floods. These Haors are predicted to experience severe stress because of changes in rainfall and temperature patterns.

The study area lies in the Meghna Basin which is part of the Ganges-Brahmaputra-Meghna (GBM) basins. Flow from about 66,640 km^2 of the Meghna basin is drained ultimately into the Bay of Bengal through the Kalni-Kushiyara and Surma-Baulai river system. The estimated outflow of water from this region into the Bay amounts on average is 162,619 million-m^3 year. Fifty seven (57) percentage of this flow is generated at the upstream of Bangladesh while 43% is generated within the country. Transboundary flow from India to Bangladesh varies from time to time whereas the inflow (mainly pre-monsoon flow) from India into Bangladesh is the main cause of flash flood in the Haor area (BHWDB, 2012).

The main objectives of the study is to explore the spatio-temporal potentialities of utilizable surface water and groundwater availability whether surplus or deficit from the demand and supply requirement of Austagram, Bajitpur, and Bhairab Upazila of Kishoreganj district; Atpara, Barhatta, and Durgapur Upazila of Netrokona district and Bishwamvarpur, Chhatak, and Dakshin Sunamganj Upazila of Sunamganj district.

Methodology

Study site

The study was conducted at Austagram, Bajitpur, and Bhairab Upazila of Kishoreganj district; Atpara, Barhatta, and Durgapur Upazila of Netrokona district and Bishwamvarpur, Chhatak, and DakshinSunamganj Upazila of Sunamganj district which lies in Mymensingh, Dhaka and Sylhet division respectively (Fig. 1). The study areas i.e. nine upazilas of three districts are located (91°0'00" E and 25°0'00"N) mostly north east and a little part in the north central hydrological region of Bangladesh.

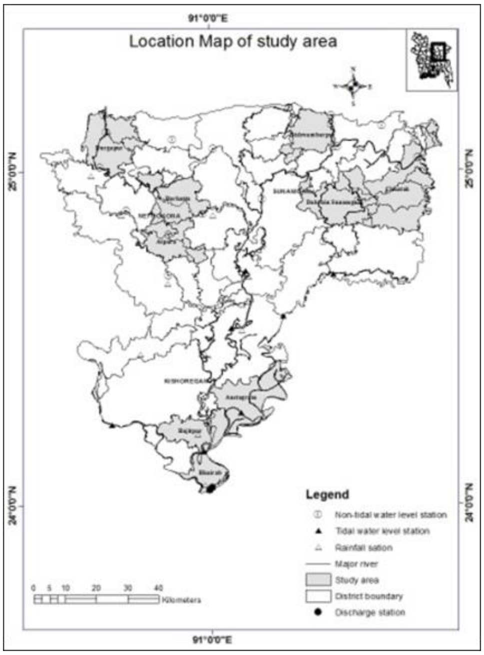

Fig. 1. Location map of the study area

The geographical feature of the study area is plain terrain with a mild slope, riverine, vegetative cover, and distinct scenario of perennial water bodies like haor, baor and beels etc,

Data processing approach

In this study all secondary data are used to assess the surface water condition specifically like rainfall, evaporation, surface water level and discharge, groundwater level has been updated in terms of validation test i.e. randomness test, consistency test, correlation test; compilation test i.e. normal distribution, T-test, F test; frequency test and goodness of fit test i.e. chi-square test etc. Due to the lack of data, groundwater analysis in Sunamganj district, utilizable river flow volume analysis at Bhairab and Durgapur Upazila have been omitted. Overall data quality is best fitted and consistent to analysis.

Rainfall analysis

In this study, the rainfall data of BWDB stations over a longer period of time from 1965 to 2012 have been analyzed as the gridded value of uniformly squared interval from which subsequent monthly average rainfall has been depicted in the graph to represent the temporal trend, availability, and variability of rainfall.

From the mean and standard deviation of monthly rainfall, monthly 80% dependable Rainfall (mm) was calculated as follow,

80% Dependable Rainfall = Mean - 0.84 × Standard Deviation

Evapotranspiration analysis

The dynamic process by which water is transferred from the soil and land surfaces to the atmosphere and by transpiration from plants. In this study, Assessment of Evapotranspiration has been calculated from Jan 1965 to Dec 2012 by using Penman-Monteith method from five parameters namely maximum and minimum temperature, relative humidity, wind speed and sunshine for study area from the adjacent meteorological stations of BMD.

Utilizable surface water

Stream flows and static water are considered the main source of surface water resources during the dry season. Median flow leaving the 80% dependable flow in the stream is considered as available or utilizable stream flow. Median static water leaving the 80% dependable static water in the natural storage system is considered as available or utilizable static water.

Crop water demand

The crop water requirement ETc in dry season has been calculated in mm from the product of crop coefficient Kc and reference crop evapotranspiration (ETo) as follows

$$ET_c = K_c \times ET_o$$

Where,

K_c = crop coefficient (crop type, stage of growth)

ET_o = reference crop ET

From the arable land area of each Upazila and crop water requirement ET_c, monthly crop water demand have been calculated for dry season in volume in MCM.

Usable groundwater

Resultant Ground Water Resource less 25% of it in account of limitations (e.g. drainage, abstraction difficulty etc.) is considered as Usable Groundwater Resource.

Results and Discussion

The results and discussion are based on the monthly average rainfall, 80% dependable rainfall, average evapotranspiration, utilizable river flow, static water, water supply requirement, crop water demand, useable groundwater, accumulative surplus or deficit water resources in the dry season of the study area.

Rainfall

The long-term monthly average rainfall (1965 to 2012) trend in the study area is the same for all the Upazila. Most of the rainfall peaks occur from June to August and mostly in July. All of the rising limbs is extended up to the month of July and after that recession starts. About 19% to 29% of rainfall of study areas occurs from November to May which covers dry season. The completely dry season is November to February when monthly average rainfall is less than 40 mm which necessitate dry seasonal surface water augmentation to reduce the stress on groundwater. The maximum annual rainfall 5649 mm occurred at Bishwamvarpur and minimum rainfall 2180 mm occurred at Bajitpur. The monthly maximum rainfall 1337 mm occurred at July at Bishwamvarpur Upazila (Fig. 2). The total rainfall of all the Upazila is near about or more than the national annual mean rainfall. The rainfall scenarios show potentialities of surface water storage in wet season for subsequent use in the dry season for agriculture and other uses. The change of rainfall pattern is remarkable in the study area.

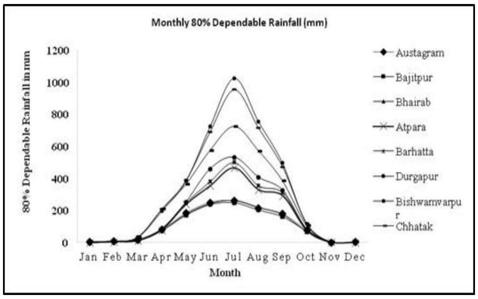

Fig. 2. Monthly Average Rainfall (mm)

Dependable rainfall

The 80% Dependable Rainfall is the value of monthly rainfall that indicates exceedance may occur 80% of the time. This value ensures that on average there will be enough available water to meet the crop's need four out of every five years. The highest 80% dependable rainfall 1026 mm was found in Sunamganj district (Fig. 3).

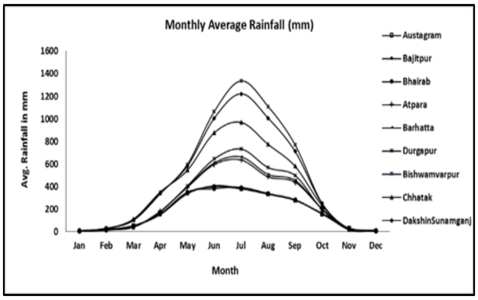

Fig. 3. Monthly 80% Dependable Rainfall (mm)

Evapotranspiration

The long-term monthly evapotranspiration trend is the same for all Upazila. The rate of evapotranspiration depends on the climatic condition. With seasonal variation, the rate of evapotranspiration fluctuate. This study shows that in the month of March, April and May rate is higher where April shows maximum rate 150 mm and average about 139 mm. In this study Kishoreganj district indicates higher evapotranspiration rate in comparison with Netrokona and Sunamjganj. The study indicates that from June to December the rate is decreasing whereas from January to April it indicates an increasing pattern. The long-term monthly evaporation trend was also the same for all of the Upazila. Evapotranspiration showed an increasing trend during the dry season which was about 57% to 58% of total evapotranspiration spanning from November to May. Total evaporation of the study area ranges from 1219 to 1323 mm respectively (Fig. 4).

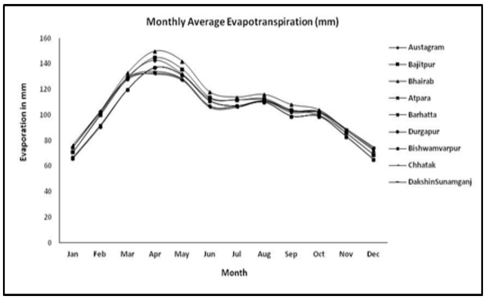

Fig. 4. Monthly Average Evapotranspiration (mm)

Utilizable river flow

In the study area, the total utilizable static water volume of the dry season is only 2% of total utilizable river flow volume. Utilizable static water sources like ponds, artificial lake, and perennial lakes are not a significant amount in this study area to fulfill the demand. In Kishoreganj, the highest river flow in the dry season in the month of November is 2382 million cubic meter (MCM) at Bajitpur Upazila whereas the lowest river flow was 321 MCM (Table 1). From April to upward till November the river flow shows an increasing pattern whereas from December to March it indicates a decreasing pattern. In this point of view, it is clearly shown in the rainy season; the river flow is higher compared to dry season. Netrokona and Sunamganj indicate lower river flow in comparison with Kishoreganj which is 04 MCM in Dakshin Sunamganj.

Utilizable static water

It is evident that water volume increases in the wet season whereas it decreases in the dry season. Since this study based on a dry period where April and May show the maximum water volume in comparison with rest of the month. The highest static water is utilized at Chhatak in Sunamganj district is about 95.6MCM whereas in Kishoreganj and Netrokona is used lower amount (Table 2). However, Poor storage depicts the demand of irrigation.

Water supply requirement

The water supply requirement is the highest at Bhairab in Kishoreganj is 1.2 million cubic meter in comparison with another district (Table 3). The increase of water supply requirement indicates either the more water is used in crop productivity or more water is used in domestic purposes. In Sunamganj, excessive water is used at Chhatak Upazila is 1.0 MCM related to Bishwamvarpur and Dakshin Sunamganj Upazila. Therefore, besides using surface water, the withdrawal of groundwater is increasing

Table 1. Utilizable river flow volumes in the dry season in MCM

District	Upazila	Nov	Dec	Jan	Feb	Mar	Apr	May
Kishoreganj	Austagram	1,915	404	405	327	706	1,069	2,074
	Bajitpur	2,382	219	348	347	383	321	986
Netrokona	Atpara	43	22	17	13	13	33	165
	Barhatta	118	19	7	8	9	52	283
Sunamganj	Bishwamvarpur	124	139	96	82	96	99	106
	Chhatak	256	46	37	45	157	520	705
	Dakshin Sunamganj	147	15	6	4	17	81	120

Note: Utilizable River Flow Volumes in Dry Season for Bhairab and Durgapur is not estimated due to lack of data.

Table 2. Utilizable static water volumes in the dry season in MCM

District	Upazila	Nov	Dec	Jan	Feb	Mar	Apr	May
Kishoreganj	Austagram	0.2	0.0	0.0	0.0	0.0	0.7	35.5
	Bajitpur	0.0	0.0	0.0	0.0	0.0	0.1	5.7
	Bhairab	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Netrokona	Atpara	0.2	0.0	0.0	0.0	0.0	0.8	9.6
	Barhatta	0.2	0.0	0.0	0.0	0.0	1.4	8.4
	Durgapur	0.0	0.0	0.0	0.0	0.0	0.0	5.4
Sunamganj	Bishwamvarpur	7.2	9.7	3.6	4.1	3.8	13.9	56.7
	Chhatak	0.0	0.0	0.0	0.0	0.0	0.2	95.6
	Dakshin Sunamganj	1.0	0.0	0.0	0.0	0.0	7.8	56.7

Table 3. Water supply requirement in the dry season in MCM

District	Upazila	Nov	Dec	Jan	Feb	Mar	Apr	May
Kishoreganj	Austagram	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Bajitpur	0.8	0.8	0.8	0.8	0.8	0.8	0.8
	Bhairab	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Netrokona	Atpara	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Barhatta	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Durgapur	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sunamganj	Bishwamvarpur	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Chhatak	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Dakshin Sunamganj	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Crop production

Crop production of the study area has been calculated according to BBS data collected from the National Water Resources Database (NWRD), WARPO. In this research, the crop production data from 1974-1990 has used. Therefore, the data shows that the highest avg. production of the crop is at Chhatak, Sunamganj district in 1980-81 which is approximately 5284 metric tonnes (Table 4) and no crop has produced at Bishwamvarpur, Sunamganj in 1974-83. After 1983 the area gradually started cultivation and in 1983-84 the crop production is approximately 574 metric tons. According to area and production of rice crops of BBS, 2013 (Aus, Aman, and Boro) in 2009-2011, it has been noticed that Aus production is decreasing in comparison with Aman and Boro (Table 5)

Table 4. Crop Production (in M.ton)

District	Upazila	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82
Kishoreganj	Austagram	3399	3986	3874	3239	2741	3293	3740	3982
	Bhairab	1106	1330	1093	998	868	973	895	1111
Netrokona	Durgapur	2855	3704	4436	3328	3991	3098	3789	4044
	Atpara	1092	1129	1446	1459	1121	1094	172	1564
	Barhatta	1634	1869	1529	444	1544	1368	2040	2011
Sunamganj	B.pur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Chhatak	3321	3537	2943	4251	4441	5039	5284	4873

contd.

contd.

District	Upazila	82-83	83-84	84-85	85-86	86-87	87-88	88-89	89-90
Kishoreganj	Austagram	3560	3560	4211	3230	3400	3558	3112	3112
	Bhairab	1369	1628	1695	1420	1749	1712	1659	2083
Netrokona	Durgapur	3914	4000	4086	2819	3542	3768	2988	3190
	Atpara	1278	1278	995	1337	1714	2290	1918	2083
	Barhatta	1777	2535	1601	2104	2148	2999	1379	1556
Sunamganj	B.pur	0.00	574	549	1048	673	1241	1206	1179
	Chhatak	4758	5009	1326	1509	3924	1559	1633	2424

Note: B.pur: Bishwamvarpur

Table 5. Area and production of rice crops in the study area (Mton)

District	Upazila	2009-2010					
		Aus		Aman		Boro	
		Area	Production	Area	Production	Area	Production
Kishoreganj	Austagram	0	0	397	348	56181	81039
	Bajitpur	74	67	4347	4556	16974	28070
	Bhairab	550	560	17000	19880	3700	53400
Netrokona	Atpara	1547	1268	25179	23651	27608	44083
	Barhatta	145	113	37504	37171	33777	49862
	Durgapur	15	25179	22	27960	4044	580
Sunamganj	Bishwamvarpur	988	1080	20501	18675	27664	33210
	Chhatak	469	367	21390	14868	37565	26494
	Dakshin Sunamganj	0	0	41891	3986	43767	35314

contd.

contd.

District	Upazila	2010-2011					
		Aus		Aman		Boro	
		Area	Production	Area	Production	Area	Production
Kishoreganj	Austagram	0	0	327	4010	60665	103126
	Bajitpur	91	98	3507	3692	16166	26808
	Bhairab	600	600	18000	20880	3500	52257
Netrokona	Atpara	495	375	24166	21128	28053	45907
	Barhatta	50	40	37505	36156	34025	53975
	Durgapur	51	33	40714	38626	45085	93904
Sunamganj	Bishwamvarpur	1750	1740	21000	17609	27605	35042
	Chhatak	617	526	23082	16995	37664	59696
	Dakshin Sunamganj	0	0	4710	6807	45201	73314

Crop water demand

Crop water demand depends on soil, meteorological and crop physiological factor and important in irrigation scheme design. In the studied agro-based area, monthly crop water demand during the dry season is crucial due to being stapled consuming sector of water use. The irrigated area in Kishoreganj is 55.14% which indicate the importance of irrigation in the Haor region (BBS, 2012). The total demand for the study area is found about 712 MCM and maximum water demand 127 MCM for Chhatak and minimum water demand 41 MCM for Bhairab (Table 6). Monthly utilizable surface water volume is enough to meet the demand. But due to the lack of surface water based irrigation system management, groundwater is also lifted for irrigation purpose. The net cultivable area in Austagram, Bajitpur, and Bhairab are 243.53, 132.56 and 87.34 sq. km respectively. Statistically, crop water demand in some month of a year may be zero due to no irrigation. The monthly crop water demand is highest in a drier month due to higher evaporation demand. The maximum crop water demand was found in March for Austagram. The minimum crop water demand indicates the sufficiency of dependable rainfall.

Table 6. Monthly crop water demand in the dry season in MCM

District	Upazila	Nov	Dec	Jan	Feb	Mar	Apr	May
Kishoreganj	Austagram	0.0	0.3	18.0	25.4	36.7	32.2	0.0
	Bajitpur	3.5	0.4	8.7	12.0	17.3	17.7	2.9
	Bhairab	2.9	0.3	5.5	7.6	10.9	11.6	2.3
Netrokona	Atpara	4.5	0.2	8.7	12.1	17.5	15.7	0.4
	Barhatta	6.6	0.2	9.5	13.3	19.2	17.3	0.5
	Durgapur	8.5	0.3	11.8	16.5	23.8	21.5	0.7
Sunamganj	Bishwamvarpur	5.0	0.1	0.1	11.0	17.3	17.8	14.5
	Chhatak	4.5	0.1	0.1	22.7	35.6	35.6	28.6
	Dakshin Sunamganj	1.4	0.0	0.0	17.4	27.2	26.9	21.6

Usable groundwater

The concept of monthly usable groundwater volume is recognized by the Bangladesh Water Act 2013 which permits groundwater use within safe yield limit (WARPO, 2013). Groundwater is the only source of drinking water in haor and entire Bangladesh except metropolitan areas where surface water treatment plant available. The spatial utilizable groundwater volume for all the study Upazila is very limited with a total maximum of 83.5 MCM at Atpara and total minimum 6.5 at Durgapur (Table 7). There is no usable groundwater in April-May for all the study area. The use of groundwater during April-May due to unavailability of alternative sources may cause mining. Both the usable groundwater and surface water sources are very limited at Durgapur. The usable groundwater shows decreasing trend at dry season (Nov to May) for all the data analyzed Upazila due to low recharge, groundwater withdrawal by Low lift Pump, deep tube well, Hand tubewell and shallow tubewell. Usable groundwater volume indicates the storage and yielding capacity of the aquifer. In respect to storage availability, Atpara Upazila indicates good quality aquifer compared to others.

Table 7. Monthly usable groundwater volume in the dry season in MCM

District	Upazila	Nov	Dec	Jan	Feb	Mar	Apr	May
Kishoreganj	Austagram	10.1	9.6	9.1	3.1	0.0	0.0	0.0
	Bhairab	21.7	17.6	16.1	9.4	0.7	0.0	0.0
Netrokona	Atpara	26.0	21.7	21.2	13.0	1.6	0.0	0.0
	Barhatta	19.6	14.6	14.0	6.8	0.0	0.0	0.0
	Durgapur	6.5	0.0	0.0	0.0	0.0	0.0	0.0

Note: Usable groundwater volume for Bajitpur Upazila and Sunamganj District is not estimated due to lack of data

Accumulative surplus/deficit

The surplus or deficit depends on how much water is used or how much water is a shortage in the mentioned time frame November to May. The maximum shortage of water shows -34.5 million cubic meters at Bajitpur in Kishoreganj following -28.7 and -27.7 million cubic meters at Austagram and Bhairab respectively. The shortage of water also noticeable in February, March, and April whereas Bajitpur shows the entire time frame. Besides the deficit in November, December and January show a surplus of water. The present study indicates that the sufficient water supply in November to January is 21.7 MCM whereas from February to May the shortage of water is noticeable which are -80.5 MCM at Atpara and Durgapur respectively (Table 8). In comparison with Netrokona to Kishoreganj, the maximum shortage of water shows Durgapur, Netrokona district which indicates either environmental flow of water is disrupting or the withdrawal of water is increasing. The entire time frame in Sunamganj from November to May shows the shortage of water where in May indicates maximum -81.0 at Chhatak and in November minimum -0.4 at Bishwambarpur Upazila. This means withdrawal of an excessive amount of groundwater not using surface water or water supply disruption by constructing a dam or such type of structure.

Table 8. Monthly (accumulative) surplus or deficit water resources in the dry season (MCM)

District	Upazila	Nov	Dec	Jan	Feb	Mar	Apr	May
Kishoreganj	Austagram	9.6	9.1	3.1	-5.4	-17.6	-28.2	-28.7
	Bajitpur	-2.4	-3.3	-8.2	-14.5	-23.4	-32.4	-34.5
	Bhairab	17.6	16.1	9.4	0.7	-11.4	-24.2	-27.7
Netrokona	Atpara	21.7	21.2	13.0	1.6	-14.6	-29.2	-29.9
	Barhatta	14.6	14.0	6.8	-3.2	-17.3	-30.1	-30.9
	Durgapur	-2.6	-3.4	-15.8	-32.8	-57.2	-79.2	-80.5
Sunamganj	Bishwambarpur	-0.4	-0.8	-1.2	-5.3	-17.3	-29.6	-39.7
	Chhatak	-3.6	-4.7	-5.7	-19.9	-41.6	-63.3	-81.0
	Dakshin Sunamganj	-0.5	-1.0	-1.4	-15.1	-26.3	-37.4	-46.3

Conclusion

The Haor area is considered as the most productive wetland resources of Bangladesh which depend on the availability and high potentiality of surface water storage and use. About 19% to 29% of rainfall of study areas occurs from November to May. Evapotranspiration showed about 57% to 58% of total evapotranspiration spanning from November to May. The highest river flow in the dry season in the month of November is 2382 million cubic meter (MCM) whereas the lowest river flow was 321 MCM. The highest avg. production of the crop is at Chhatak, Sunamganj district in 1980-81 which is approximately 5284 metric tonnes. The present study indicates that the sufficient water supply from November to January is 21.7 MCM whereas from February to May the shortage of water is noticeable which is -80.5 MCM. Groundwater use in April-May, therefore, may tend to mine.

Due to a shortage of both surface and groundwater in Durgapur necessitate development activities to prevent mining. Further study is necessary to find out the scope of surface water storage, distribution and use due to the availability of streamflow, static flow, and rainfall. The food production is essential in the study area by utilizing groundwater or surface water for the development of national economy. Since the study area faces enough shortage of water, therefore, it is necessary to change the cropping pattern, to introduce water conserving and drought tolerant crops. Rainfall or evapotranspiration is a natural process so this flows cannot possible to impede by human beings rather using rainwater or as much as possible by harvesting. The construction of a dam or structures over the channel may hamper the static flow of the river. Since water is a valuable national resource, therefore, the public awareness should increase and proper implementation of the Bangladesh Water Act is essential to ensure the maintenance of usable water.

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