ASSESSMENT OF AGRICULTURAL WATER AND ENVIRONMENTAL FLOW DEMAND FOR BANGLADESH

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ABSTRACT

The Bangladesh, renowned for its riverine landscape and fertile land, has a historical foundation in agriculture. Despite its capability to sustainably produce food for its populous nation, recent industrialization and urbanization have caused a shift in economic dynamics. This shift is evident as agriculture's contribution to the GDP lags behind that of industries, attributing the disparity to the diminishing availability of cultivable land. Being reliant on river water for irrigation, agriculture in Bangladesh has a massive influence on the ecology. This study focuses on the agricultural water demand and environmental flow demand of rivers in Bangladesh. For the calculation of agricultural water demand, different types of crops and their corresponding water requirement is considered. The crop data in seven of the eight hydrological zones of Bangladesh according to the National Water Management Plan (NWMP) has been studied. The agricultural water demand is calculated using the CROPWAT & CLIMWAT tool. The required data input is given to calculate agricultural water demand in Bangladesh. The total agricultural water demand is estimated to be approximately 58 billion cubic meters. The North-Western zone, as expected, has the highest demand, while the Eastern Hills zone has the lowest. Notably, temporal variation is observed, with the highest demand occurring between November and April during the dry season. Additionally, this study delves into the critical aspect of environmental flow requirements of the major rivers of Bangladesh. The discharge data from fifteen major rivers covering all of Bangladesh's hydrological zones are used to determine the country's overall environmental flow employing the Tennant method. This study investigates the capacity of river environmental flow to satisfy Bangladesh's substantial agricultural water demand. By investigating both agricultural and environmental flow requirements, this study aims to contribute essential insight to sustainable water resources management in Bangladesh.

Keywords: *Agricultural water demand, environmental flow, hydrologic zones, Bangladesh, water resources management.*

1. INTRODUCTION

The Water is an important element of natural resources. Water is needed for agricultural, industrial, domestic, commercial, navigational, and environmental purposes (environmental flow of rivers, evapotranspiration, etc.) (Ahmed & Roy, 2007). Environmental water demand is defined as the water required for stability of river's ecosystem. Changes in the river flow affects the water quality as well as aquatic habitats of rivers. As Bangladesh is a riverine country, the mean annual discharge from the combined major rivers was found to be 981 cubic kilometres for the period 1980 to 2009, with flow declining to as low as 15% of the annual mean during the dry period of the year (November to April), with the Brahmaputra accounting for as much as 75% of the dry season flow (CSIRO, 2014). The transboundary rivers bring about 1000 billion cubic meters to the country, which cannot meet the requirement during the dry season (Abu Musa, 2007). Several reasons work behind this situation. Bangladesh is geographically situated at the downstream faces of all rivers generated from the Himalayas. So, the constant advancement, autonomous withdrawal of water from the major rivers, and controlling propensity in the upstream faces cause an overflow of water during the wet season producing the flood as well as a reduced flow in all transboundary rivers during the dry season. So, the environmental water requirement is needed for conservation of freshwater while the available water can meet the human water demand.

The water is needed for various purposes: irrigation, domestic uses, industrial uses & environmental flow requirements. Bangladesh is chiefly an agrarian country, with the irrigation water demand composing the lion's share of the total water demand of Bangladesh. Besides irrigation, other waterdemanding sectors include domestic and municipal uses, industry, fisheries, navigation, evaporation, and environmental water requirements. Although they comprise a minor portion of the total water demand, their implication can be significant, especially on local scales. In many cases, environmental water demand is overlooked, and natural rivers and wetlands are completely depleted in the dry season to supplement water for other sectors.

According to the National Water Management Plan 2001, Bangladesh has been divided into eight distinct hydrological regions considering the principal rivers and the natural geographical features as boundaries. These 8 regions are Northwest (NW), North Central (NC), Northeast (NE), Southeast (SE), South Central (SC), Southwest (SW), Eastern Hills (EH), plus the active floodplains and char lands of the Main Rivers and Estuaries (RE) (WARPO, 2001). Each hydrological zone has a distinct climate and pronounces differences in demographic and hydrologic features. Therefore, the National Water Management Plan focuses on adopting region-wise strategies to pursue the water resources needs and challenges which finally agglomerate into the National Water Management Plan.

(Akter, 2020) estimated the irrigation water demand for a selected irrigation unit. (Akter, 2012) estimated the environmental water demand for Halda river. (Mullick et al 2012) estimated the environmental water demand for the Teesta River, Bangladesh. The main objective of this study is to assess the environmental water demand of the major rivers of Bangladesh and irrigation water requirement for two seasons i.e., dry season (October-March) and wet season (April- September) of each hydrologic zone.

2. METHODOLOGY

Water is required for every purpose from the beginning to the end of the day. The water demand in Bangladesh is driven by various sectors, reflecting the diverse needs of its population and economy. Understanding these sectors is crucial for effective water resources management. But the major demand sector implies agricultural water demand and environmental water requirement which had been addressed in this study.

2.1 Environmental Water Requirement

Environmental flow or E-flow is defined as the flow of water in a river system to keep the ecosystem stable. The diversity of species in a river environment poses resource managers with a challenge in achieving ideal circumstances for all species at the same time. To address this issue, the focus has switched from a minimum flow strategy to one that begins with the river's "natural" regime.

Environmental flow assessment (EFA) is concerned with determining the required river flow regime that can be achieved without creating any adverse effects (Akter A et. al., 2012). There are several approaches for environmental flow assessment. The available methods are divided into four categories such as (i) hydrologic methods using historical hydrological data, (ii) hydraulic methods based on the hydraulic properties of river sections, (iii) habitat simulation methods built on habitat suitability analysis (iv) Holistic methods considering various factors. Among these methods, hydrologic methods are greatly adopted globally because of low data requirements (only flow data) and convenience (Ni, X et. al., 2022).

Tennant (1976) developed a method of assessing E-flow using hydrological data of hundreds of rivers in the mid-western of USA. The percentages of mean flow that provide varied quality habitats for fish are stated, for example, 10% for poor quality (survival), 30% for moderate habitat (good), and 60% for outstanding habitat. In this study, the Hydrological method of Tennant has been used to assess the environmental flow of rivers of different hydrologic zones. According to Tennant, 10% of mean annual flow has been considered as E-flow for dry period (October-March) and 30% of mean annual flow (Excellent flow) for wet period (April-September). In Bangladesh, there are 237 rivers according to Bangladesh Water Development Board (BWDB). But it was difficult to collect the discharge data for all rivers as the authority only collects the discharge data for major rivers of Bangladesh. In this research, 19 river stations have been collected and the data year has been shown in table 2.1. To select the hydrologic zones of the river, the basin area of the rivers has been calculated with the help of GIS software. The basin fraction has been shown in table 2.2 and figure 2.1.

Table 2.1: Data Timeframe of Different Rivers

River Name	Station	Data-Year
Old Brahmaputra	230.1	1979-2019
Halda	SW 119.1	1983-2019
Surma	SW 266	1980-2019
kushiyara	SW 173	1969-2019
Jamuna	SW 46.9 L	1976-2019
Teesta	SW291.5R	1979-2019
Teesta	SW 294	1985-2016
Dudhkumar	SW 81	1996-2019
Dharla	SW 76	1996-2019
Gorai Modhumoti		1980-2019
Ganges-Padma-Mawa	SW 93.5L	1994-2019
Ganges-Padma-Hardinge Bridge	SW 90	1969-2019
Jadukata	SW 131.5	2021
Arial Khan	SW 4A	2021
Bhogai Kangsha	SW 36	2021
Ganges-Padma- Baruria	SW 91.9 L	2016-2018
Dhala	SW 332	2021
Noyagang	SW 337	2021
Piyan	SW 233	2021
Sangu		2005-2006

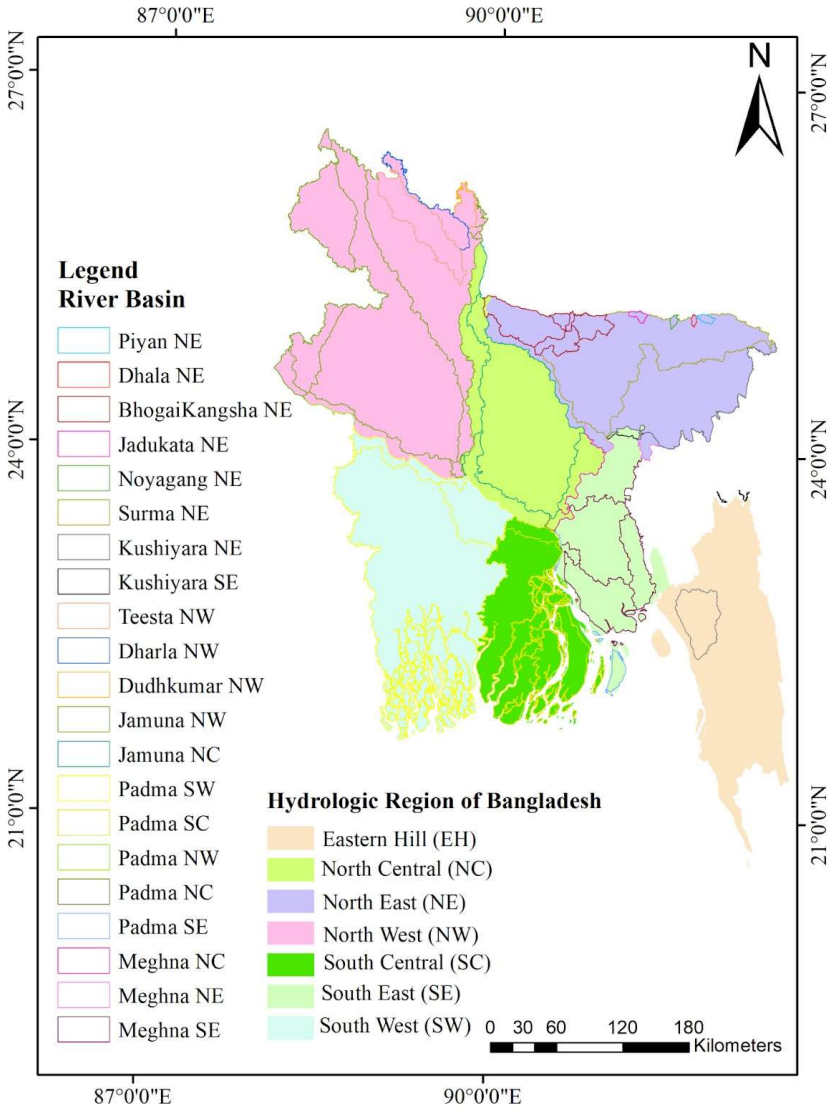

Figure 2.1: Basin Fraction of Rivers

2.2 Agricultural Water Demand

Agricultural water demand is also called irrigation water demand which refers to the demand for water used for agricultural purposes such as irrigation. This demand depends on the various factors such as land use, cropping pattern, soil type, evapotranspiration, rainfall, percolation etc. The Food and Agricultural Organization (FAO) has introduced a numerical model called CROPWAT incorporating CLIMWAT which helps to calculate the irrigation water demand from climate, crop and soil data. This model consists of the Penman-Monteith method for calculating the potential evapotranspiration (Smith, 1992), USDA soil conservation method to calculate effective precipitation and the calculation of crop water requirements based on the FAO irrigation and drainage paper. (Akter, 2020).

CLIMWAT is a tool used for climatic database incorporating with CROPWAT to determine the irrigation water requirements. This tool contains 5000 stations worldwide to provide the seven climatologic parameters such as mean daily maximum temperature, mean daily minimum temperature, mean relative humidity, mean wind speed, mean sunshine hour, mean monthly rainfall, mean monthly effective rainfall, mean solar radiation and reference evapotranspiration.

The crop calendar for different crops and the irrigated area for different hydrological zones has been collected from Bangladesh Yearbook of Agricultural Statistics 2015 (Table 2.11). The climate data such as rainfall and soil data has been collected from Bangladesh Meteorological Department. Using CROPWAT software monthly irrigation water requirement for every crop was calculated. Then, the crop water requirement is concluded in two periods such as dry period (October- March) and wet period (April-September) and divided into every month to get equal distribution for demand.

Table 2.2: Irrigated Area for Different Crops in 2015

Crop name	**Irrigated Area (ha)**						
	South central	Southeast	Southwest	Northeast	Northwest	Northcentral	Eastern Hill
Aus	261641	183335	168503	146699	203516	18729	62985
Aman	732287	520540	835124	779252	1854385	511806	296620
Boro	212735	449445	716792	1001337	1609603	712270	138048
Wheat	14369	4359	123069	5513	270375	19128	4
Tobacco	2	0	22977	0	22026	2385	3987
Lentil	9750	3704	79857	394	47963	3484	146
Soyabean	1735	46137	0	2	8	2	0
Sugarcane	2271	1339	19364	3031	65241	11170	1803
Banana	4875	1684	9932	2989	9043	9136	9056
Cauliflower	549	1454	4599	2040	6907	2799	1197
Cabbage	649	1124	4874	1911	5494	2390	1271
Tomato	1762	4023	3988	2839	12648	2772	2564
Radish	1328	2812	4304	3642	7118	3986	2747
Potato	11195	30574	15546	17586	332813	57449	5850
Sweet Potato	4182	6799	1113	2574	3813	3695	3073

3. ILLUSTRATIONS

3.1 Environmental Water Requirement

Environmental water demand varies significantly seasonally. In this case, the environmental water demand for the dry season is 10% of the mean annual flow and 200% of the mean annual flow during the wet season. Using only main rivers in Bangladesh, the total environmental water demand was 146.45 BCM for dry period & 2761.72 BCM for wet period, with the Southeast hydrologic zone having the highest demand and the Eastern Hill having the lowest. Only the Padma River was collected in the south (South Central & Southwest) of Bangladesh, whereas the Halda River and Sangu River were taken in the eastern hill region, demonstrating the variety in the demand. In this study, the annual flow data for the river was obtained from the Bangladesh Water Development Board (BWDB). Table 3.1 shows the average annual flow for the rivers studied as well as table 3.2 demonstrates the monthly environmental water demand for different hydrologic zones.

Table 3.1: Mean Annual Flow of Rivers

River name	Mean Annual Flow		
	Dry Period(Oct-Mar)	Wet Period(Apr-Sep)	MAF
Brahmaputra	54.889	132.267	98.414
Halda	18.059	59.783	39.296
Surma	149.478	977.555	563.517
Kushiyara	311.671	1158.155	738.61
Jamuna	10274.71	30118.03	20366.6
Teesta -1	188.577	883.161	549.761
Teesta-2	310.207	1434.477	864.38
Dudhkumar	212.826	638.885	424.909
Dharla	190.729	772.167	472.404
Gorai	479.215	1780.267	1142.622
Ganges-Mawa	39484.75	55517.4	52282.74
Ganges-Hardinge Bridge	5141.868	15831.25	10531.66
Jadukata	42.866	306.382	174.624
Bhogai-Kangsha	68.02	513.046	290.533
Dhala	15.338	185.894	100.616
Noyaganj	1.624	27.557	14.59
Piyan	2.262	25.737	17.912
Sangu	27.944	131.86	79.902
Arial Khan	218.275	682.406	450.34
Ganges-Baruria Transit	14872.08	40315.02	27593.55

Table 3.2: Environmental Water Demand of Different Hydrologic Zones

Hydrologic Zone	Dry Period(10%MAF)(BCM)	Wet Period(200%MAF)(BCM)
Northeast	11.64	50.73
Northwest	39.03	784.87
Northcentral	3.40	68.46
Southeast	1.12	22.49
Southwest	62.59	1258.74
Southcentral	28.48	572.66
Eastern Hill	0.19	3.77

3.2 Agricultural Water Requirement

Agriculture is the most water-intensive sector in Bangladesh, consuming the greatest proportion (88.38%) of overall water consumption. Using 15 important crops, it was determined that the net irrigation water use in 2015 was 55.078 BCM to 58.478 BCM in 2018. The demand for irrigation water changes substantially throughout the year. The demand is displayed here by computing the demand for two periods and distributing it equally in each month. During the dry season (OctoberMarch), all hydrological zones demand more water, with the Northwest hydrological zone requiring the most and the Eastern Hill hydrological zone requiring the least. Table 3.3 depicts the irrigation water requirements for every hydrologic zone.

Table 3.3: Irrigation Water Demand of Different Hydrologic Zones

Year	2015 (BCM)		2016 (BCM)		2017 (BCM)		2018 (BCM)	
Hydrologic Zone	**Dry Period**	**Wet Period**	**Dry period**	**Wet Period**	**Dry Period**	**Wet Period**	**Dry period**	**Wet Period**
Northeast	8.209	0.683	8.242	0.852	6.250	0.855	8.507	0.733
Northwest	17.995	3.298	18.283	3.374	10.247	1.287	12.300	1.545
North Central	7.726	0.813	7.730	0.806	7.616	0.806	7.858	0.837
Southeast	5.216	1.134	5.061	1.294	5.411	1.247	11.387	1.148
Southwest	6.061	0.910	6.036	0.911	4.678	0.534	6.155	0.703
Southcentral	2.267	0.738	2.174	1.075	6.713	0.471	6.825	0.479
Eastern Hill	1.49	0.48	1.41	0.53	1.90	0.15	2.31	0.18

4. CONCLUSIONS

The water demand and supply scenario in Bangladesh presents a complex and challenging situation that requires sustainable solutions. With a rapidly growing population, urbanization and industrialization the demand for water has surged, placing significant pressure on the available water resources. Bangladesh faces various issues such as over extraction of groundwater, impacts of climate change, changes in precipitation patterns and the sea level rise. From this study, it can be concluded that the environmental water demand is maximum in wet period and irrigation water demand is maximum in dry period. The amount of environmental water demand for wet period is 2761.72 BCM and for dry period is 146.45 BCM. The irrigation water demand is maximum in Northwest zone and minimum in Eastern hill regions. In Bangladesh, the water for irrigation is extracted from groundwater which is helping to decrease the aquifer level. To alleviate Bangladesh's water stress, the government must prioritize and implement water management strategies. It is necessary to understand the water shortage and surplus to build a sustainable water supply. There are some limitations in this study in assessing the demands. Only 17 crops and 20 rivers were taken into consideration to calculate the demands. To make further study, all crops and all rivers should be considered to get the full scenario of demand in Bangladesh.

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