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WATER MANAGEMENT AND CROPPING PATTERNS OPTIMIZATION FOR ENHANCED AGRICULTURAL PRODUCTIVITY IN SUNAMGANJ HAOR AREAS

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Abstract

Haors are bowl-shaped wetlands where water remains stagnant or experiences flash flooding between June and November. This study assessed current water management practices, cropping patterns, and associated challenges in the *haor* regions of Sunamganj District, using both hydro-meteorological analysis and field-based data. Primary data were collected using both qualitative and quantitative methods, including interviews and field assessments, from three Upazilas: Bishwamvarpur, Tahirpur, and Jamalgonj, involving 120 respondents. Secondary data were obtained from Upazila Administrations, Bangladesh Water Development Board, and Department of Agricultural Extension. Most respondents were farmers, and a significant portion of their cultivable land was classified as lowland. The study results show that the Rabi season is the main cropping period, while lands remain fallow during the Kharif-1 and Kharif-2 seasons due to flooding. Hydro-meteorological analysis indicates that transitioning from a single-cropping system (110-117 days) to a double-cropping pattern (174-191 days) could enhance productivity. These findings underscore the need for comprehensive technical studies on water management to assess the potential for large-scale agricultural intensification in the lowlands of the haor region, enhancing overall productivity.

Keywords: Cropping Pattern, Discharge, Floodwater, Haor, Rainfall.

Introduction

Sunamganj, a significant district in northeastern Bangladesh, is prone to flash floods from the hilly areas of India, located just above the district, which spans a total area of 3,747.18 km² (Haque *et al.,* 2017). Heavy rains from Cherrapunjee and Shillong trigger this seasonal flash flood, leading to a runoff of approximately 2,427 km². This area features the Surma-Kusiyara floodplain, a levee and basin relief that slopes from the northeast toward the west and southwest, with basin centers characterized by large permanent and seasonal depressions, known locally as ‘Haor’ (Brammer, 2012). The haor experiences flooding to a depth of 5-10 m from late May to October, creating a sea-like appearance (Sharma, 2011). These low-lying river basin areas comprise about 14% of the country’s total area and are home to approximately 19.4 million people (Uddin *et al.,* 2019). The cropping intensity and crop productivity in the haor area of Bangladesh are notably lower compared to the national average. The average cropping intensity in the haor region is 104%, significantly lower than the national average of 195% (Uddin, 2019). Cropping intensity in Sunamganj is the lowest

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(137%) among the haor region due to a large single-cropped area (Bokhtiar *et al.,* 2024).

Floods greatly impact cropping patterns and yield in floodplains, especially in numerous haors like Tanguar Haor, Banuar Haor, Motian Haor, Pakna Haor, Sanir Haor, Hail Haor, and others. Past floods in 1988, 1989, 1993, and 1996 caused severe damage to rice and other crops, exceeding danger thresholds for 60, 25, 43, and 18 days, respectively (Haque *et al.,* 2017; Abedin *et al.,* 2022; Awal 2022). In April 2016 and 2017, flash floods and hailstorms damaged the standing Boro rice crop across more than 22,000 hectares, severely affecting the national economy. To reduce flood damage, the government has taken structural steps, such as building submersible embankments to protect crops until harvest. Still, early pre-monsoon rains can overwhelm these embankments, making it necessary to change cropping patterns to handle excess water. The devastating flood from April to June 2022 affected 7.2 million people and damaged 254,251 hectares of farmland (HCTT, 2022), with total damages estimated at USD 547.6 million (Ministry of Disaster Management and Relief, 2023). This prompted the Ministry of Water Resources to form a team to suggest alternatives, including designating some haors as permanent reservoirs and growing early harvest rice varieties under emergency conditions (Masood *et al.,* 2024).

Throughout the rainy season, Sunamganj faces significant water management challenges, which are exacerbated by scarcity during the dry season. Most residents of the haor regions are traditional farmers who grow only one crop, Boro rice, due to flooding from June to October (Rahman *et al.,* 2020). Despite this single-crop system and frequent flash floods, the haor region produces over 20% of the country's total rice (BBS, 2023). Hydrological conditions play a significant role in shaping agricultural productivity, crop choices, and cropping patterns in the area (MPO, 1987). Farmers usually wait until mid December or early January to irrigate and plant Boro rice, leaving large regions fallow for about 80 to 90 days after flooding. From the last week of September to the second week of October, roughly 10-15% of the haor's land is suitable for farming (Mohiuddin and Sarker, 2019). From this study, it is assumed that introducing short-duration crops during this fallow period could help farmers increase income and transition from a single cropping system to a more productive two-crop setup, which is vital for improving food security in the country.

A study by Khan *et al.* (2012) in the Kishoreganj district found that inadequate flood control mechanisms led to flash floods damaging rice during the Rabi season. According to the Department of Agricultural Extension, the common cropping patterns in Sunamganj include Boro-Fallow-Fallow (80%), Fallow-Fallow-T.Aman (3%), Boro-Fallow-T.Aman (8%), and Fallow-Aus-T.Aman (6%). Various studies in Bangladesh and India (Kamrozzaman *et al.,* 2015; Nazrul *et al.,* 2017) show that adding a new crop without changing existing ones can significantly increase productivity and farmer profits. Alam *et al.* (2010) identified promising patterns, such as Rabi-Fallow-T.Aman and Vegetable-Aus-T.Aman in haor areas. Experiments by Mohiuddin *et al.* (2022) demonstrated that transitioning from single to double cropping can enhance yields, particularly with the Mustard-Boro-Fallow pattern. However, there is limited comprehensive research on agricultural practices and water management in the Sunamganj *haor* basin. Therefore, this study aims to assess the existing farming practices and water management systems in the

Sunamganj haor basin, analyse hydro-meteorological data to understand water availability and seasonal variations, and explore and recommend suitable cropping patterns that align with the region's water and climate conditions.

Materials and Methods

This section outlines the study area and methodology, including the philosophical framework, research strategy, and rationale for the case study. It covers the research scope, study area description, and data collection tools. Fieldwork, conducted from April 4, 2019, to January 28, 2020, utilized participatory rural appraisal (PRA) tools and secondary data sources with a structured plan for data recording and analysis.

Study area

The study was conducted in Bishwambarpur, Tahirpur, and Jamalganj Upazilas of Sunamganj District, which are the most flood-prone areas and highly productive of the Sylhet Division, Bangladesh (Fig. 1). There includes Dhanpur, Polash and Shulokhola Union of Bishwamvarpur Upazila, Tahirpur Upazila included Tahirpur Sadar, Moddho Tahirpur, Balijuri and Badhaghat Union and in Jamalganj Upazila Sachana Bazar, Jamalganj Sadar, and Uttar Tahirpur under Sunamganj district of Bangladesh. The study area was selected through consultations with stakeholders, including local NGOs, Union Parishad members, community members, and government representatives, with a focus on water management challenges. The research covered Kacharia, Sonir, Angrulir, and Halir haors, which are vital for local livelihoods, including farming and secondary businesses. Specific unions were selected to represent diverse water management practices and community resilience factors, including migration and remittance.

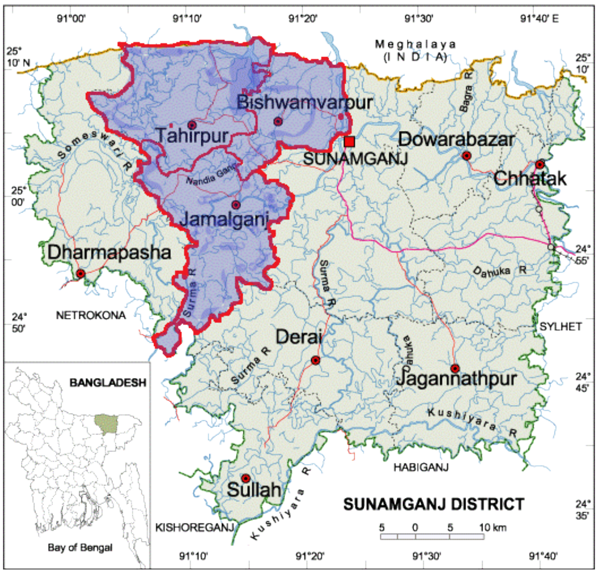

Fig. 1. Bishwambarpur, Tahirpur and Jamalgonj Upazilas of Sunamganj district.

Description of the study area

The area of Bishwambarpur Upzilla is 248.63 km², comprising 220.63 km² of land area and 28.0 km² of riverine areas. It is located between 25°01' and 25°11' north latitudes and between 91°12′ and 91°24' east longitudes. Bishwambarpur Upzilla comprises 5 Unions, 61 Mauzas, and 184 villages, and is divided into four major haors: Karcharia haor, Sonir haor, Angrulir haor, and Halir haor. Among these, Karcharia haor is the largest. To understand the temporal variability of flash floods and resource dependency with a special focus on Karcharia haor (Bishwamvarpur Upazila, 2022).

Tahirpur is situated at 25°6' N and 91°11' E, covering a total area of 313.7 km², comprising 7 unions, 131 mouzas, and 244 villages. The main haors in Tahirpur are Tanguar haor, Shanir haor, Matian haor, Karcha haor, where 'Tanguar haor' is the second largest haor in Bangladesh. There are also some rivers named 'Jadukata River', Patnai River, and Bawlai River, which come from Meghalaya. (Tahirpur Upazila, 2022).

The area of Jamalganj Upazila is 338.74 km^2, located between 24°50' and 25°04' north latitudes and between 91°05' and 91°19' east longitudes. The main rivers, including Nawa Gang, Baulai, and Dhanu Pakna Haor, are also notable. (Jamalganj Upazila, 2022).

Data collection

Primary data were collected through surveys, including questionnaires, focus group discussions (FGDs), and participatory rural appraisals (PRAs), from Bishwamvarpur, Tahirpur, and Jamalganj Upazilas. Secondary data were sourced from organizations such as the BWDB, IUCN, DAE, and the Deputy Commissioner's office, as well as journal articles, books, reports, theses, and government and NGO documents. Additionally, 30 years of hydro-meteorological data on rainfall, water levels, and discharge were analyzed to predict possible cropping patterns.

Both primary and secondary data were collected using a structured questionnaire, with surveys, semi-structured interviews, FGDs, oral histories, and transect walks. Initial informal discussions with the local community provided insights into water management, crop cultivation, social dynamics, and leaseholder challenges, shaping the focus of interviews and FGDs. A questionnaire was pre-tested with three respondents from different Upazilas. In these three Upazilas, a total of 120 people were interviewed, including both males and females, with most of them being farmers, followed by a few boatmen, shopkeepers, drivers, and businesspeople. Additionally, three key informant interviews were conducted to explore local power dynamics. Using a primarily qualitative approach, the study incorporated a quantitative element through a purposive household survey. A pilot test in three villages refined the final survey, which included 120 households across ten unions.

Interview methods

Semi-structured interviews are naturally "content-focused" and involve a guided questionnaire. Focusing on water management, semi-structured interviews were conducted at the household level. The stakeholders were identified based on water management aspects, as well as the survey questionnaire, to understand water management-related problems and the recovery process.

The oral history method captures past experiences through respondents' narratives, emphasizing individual coping strategies and adaptation to water management challenges. It provides a focused account of specific events, offering deep insights into personal and societal responses. Three oral history interviews were conducted, lasting between 2 hours 5 minutes and 2 hours 30 minutes.

Key informants are individuals who share insights based on their socio-cultural position and relationship with researchers. To aid understanding, a local guide was recruited early in the fieldwork. Three key informant interviews were conducted later, once rapport was established. For example, one informant, a peasant and NGO-nominated President of the Village Development Committee, provided valuable insights into water management struggles and power dynamics. These interviews helped reveal how influential networks operate within the community.

The first task in participatory research, or any form of qualitative research, is to construct rapport with community members, who build a sense of ownership in the overall research process. Local chronological analysis encompasses crop histories, population changes, and alterations in ecosystem services, among other factors (Choudhury, 2015). These overviews helped focus on specific issues during semi-structured interviews or Focus Group Discussions (FGDs).

A transect walk is a systematic walk with a key informant to observe, ask questions, and identify local practices (Choudhury, 2015) like water use and crop varieties. This method, combined with direct observation, helped assess community water management challenges both within villages and the haor area.

(a) FGD at Bishwamvarpur (b) FGD at Tahirpur (c) FGD at Tahirpur

Fig. 2. (a), (b) and (c) Images of focus group discussion.

Focus Group Discussions (FGDs) involved 8-10 participants with similar socio-economic backgrounds, considering factors like age, gender, and location. FGDs with farmers highlighted issues such as water shortages during peak periods, early flash floods, power imbalances, and high irrigation costs. Discussions with other occupational groups offered insights into collective community efforts in water management for productivity.

Data analysis

The survey data were checked, converted from local units to international ones, coded based on the questionnaire, and entered into Microsoft Excel and OriginPro software for descriptive statistics. Qualitative data from FGDs, semi-structured interviews, and oral histories were recorded, transcribed verbatim, and inductively coded according to the research objectives. This process generated various themes, which were used to present the findings.

Results and Discussion

Socio-economic characteristics

The characteristics of the respondents are summarized in Table 1.

Table 1. Socio-demographic characteristics profile

Sl. no.	Characteristics	Measurement	Categories	Percentages (%) of respondents (n=120)
1.	Age	Years	>20 years >30 years >40 years >50 years >60 years >70 years	7.78% 23.33% 25.56% 16.67% 13.33% 10%
2.	Income and occupation	Types of work	Agriculture Agro-farm and business Service holder Farming over driving Boatman Fishing	63% 14% 10% 6% 4% 3%
3.	Educational level attained	Year of schooling	Can't read and write Can sign only Above 5th class Above 8th class Above SSC Above HSC Above Hons.	15% 12.5% 32.5% 17% 13% 6% 3%
4.	Land ownership	Amount of land (hectares)	Landless (0) Marginal (0.2) Small (0.2-0.6) Medium (0.6-2.2) Rich (>2.2)	52.2% 12.2% 24.6% 8.2% 2.8%
5.	Water use of cultivable land	Irrigation water consumers	a. Using irrigation water b. Surface water (76.67%) c. Groundwater (23.33%) d. Without irrigation water e. With/without irrigation water (76.67% +23.33 %)	38.89% 26.66% 34.45%

The findings showed that approximately 65.56% of respondents were young to middle-aged, with agriculture being the primary source of income for 63%, while 14% relied on farming over business. Most farmers had only primary education (35%), and about 5% had secondary education. However, most respondents lacked agricultural land, with 36.8% classified as small and marginal farmers, while only 2.8% were classified as rich farmers. In terms of water use for cultivable land, 38.89% relied on surface or groundwater for irrigation, 34.45% were cultivated with or without irrigation, and 26.66% farmed without any irrigation. Furthermore, 76.67% of respondents utilized surface water, while 23.33% used groundwater, with some farmers experiencing waterlogging issues due to low-lying, cultivable lands that do not require irrigation for local rice varieties.

Land and land types in the study area

The suitable cultivable areas are 37,322, 51,590, and 55,286 hectares in Bishwambarpur, Tahirpur, and Jamalgonj Upazila, respectively. There are 3,407 hectares of entirely barren land in Bishwambarpur Upazila, 650 hectares in Tahirpur, and 431 hectares in Jamalgonj. It indicates that Jamalgonj has the least amount of barren and cultivable terrain, whereas Bishwamvarpur has the most. While entirely barren and cultivable regions quickly dried up following seasonal floods or remained submerged throughout the year, the cultivable plains are mainly used to produce Boro rice during the Rabi season. There are 2770 hectares, 1450 hectares, and 542 hectares of high land and 5190 hectares, 3370 hectares, and 5410 hectares of moderately high land in Bishwamvarpur, Tahirpur, and Jamalgonj Upazilla. 3820, 4195, and 6492 hectares are considered medium-low land; 5175, 5790, and 10550 hectares are regarded as low land; while 545, 9790, and 5080 hectares are considered very low land (Fig. 3).

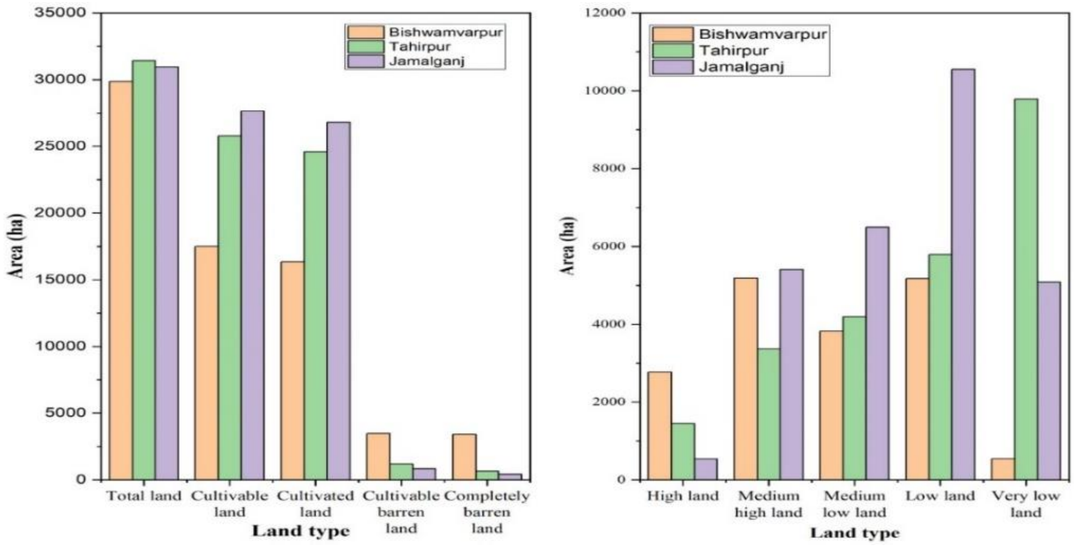

Fig. 3. Cultivable land (in hectare) and Land Type (in hectare) of Bishwamvarpur, Tahirpur and Jamalgonj Upazilla.

Most of the Haor areas in Sunamganj are comprised of medium-lowland, lowland, and very lowland, which have a significant impact on agricultural production (Khan *et al*., 2012). Results demonstrated that, since around 30% of the land is classified as high or medium-high, it has significant potential to grow two crops on the same plot of land in a single year under irrigation. There is considerably higher ground in the haor basin known locally as Kanda, which makes up 10–40% of the total Haor area, depending on the individual haor. In contrast to rice fields, which are low-lying grounds, raised Kanda lands typically experience rapid water recession and are ready for agricultural activities 30 to 45 days earlier. However, most Kanda lands remain uncultivated all year round. The lack of irrigation facilities is the only obstacle to farming in Kanda (CCC, 2009; Islam, 2010).

Existing water management problems of study areas

The following table outlines the existing water management obstacles reported by respondents at the farm level.

Table 2. Water Management Problems in the Study Areas

Sl.	Stated constraints	% farmers opined	Rank
1.	High cost of electricity	88	2
2.	Lack of supplementary irrigation	93	1
3.	High cost of diesel operating schemes	86	3
4.	Socio-economic condition of the farmer	71	5
5.	Lack of a large-scale irrigation project	76	4
6.	Extreme floods and a lack of water control	43	10
7.	Deep tube well facilities	61	7
8.	Water logging	56	8
9.	Haor bed	47	9
10.	Land topography	68	6

NB: Multiple responses considered

A significant 93% of farmers reported a lack of supplementary irrigation during the flowering stage of rice, as canals and natural water bodies have dried up. High electricity costs for irrigation affected 88% of respondents, while 86% cited the expense of diesel-operated schemes where electricity is unavailable. The absence of large irrigation projects was a common constraint, adding to the socio-economic burden of irrigation costs. The haor areas of Sunamganj District face additional challenges due to disaster-prone conditions and topography, which complicates water management. Waterlogging also varies across the region, with low-lying lands remaining wet during planting, affecting crop harvesting.

To overcome these problems, Bangladesh Agricultural Development Corporation (BADC) operates various electric-powered lifting devices to meet irrigation needs, covering 33,041 hectares. However, many personal lifting devices are unaccounted for due to their mobility and low capacity. Of the total area, 4,761 hectares of highland and 13,970 hectares of medium highland require supplementary irrigation, particularly during the flowering stage of Robi crops. Existing tube wells, powered by electricity, solar, or diesel, are insufficient to meet irrigation demands, as low-lift pumps and shallow tube wells struggle to provide adequate water coverage.

Hydro-meteorological data analysis

In Sunamganj district, the average maximum rainfall has occurred in July for 37 years (1983-2020), with an average of approximately 43.65 mm. Around 93% of the annual total rainfall occurs from April to October. On the other hand, the minimum rainfall occurs in January, at approximately 0.27 mm. More than 80% of the annual total rainfall occurs during May to October period (Rahaman *et al*., 2016).

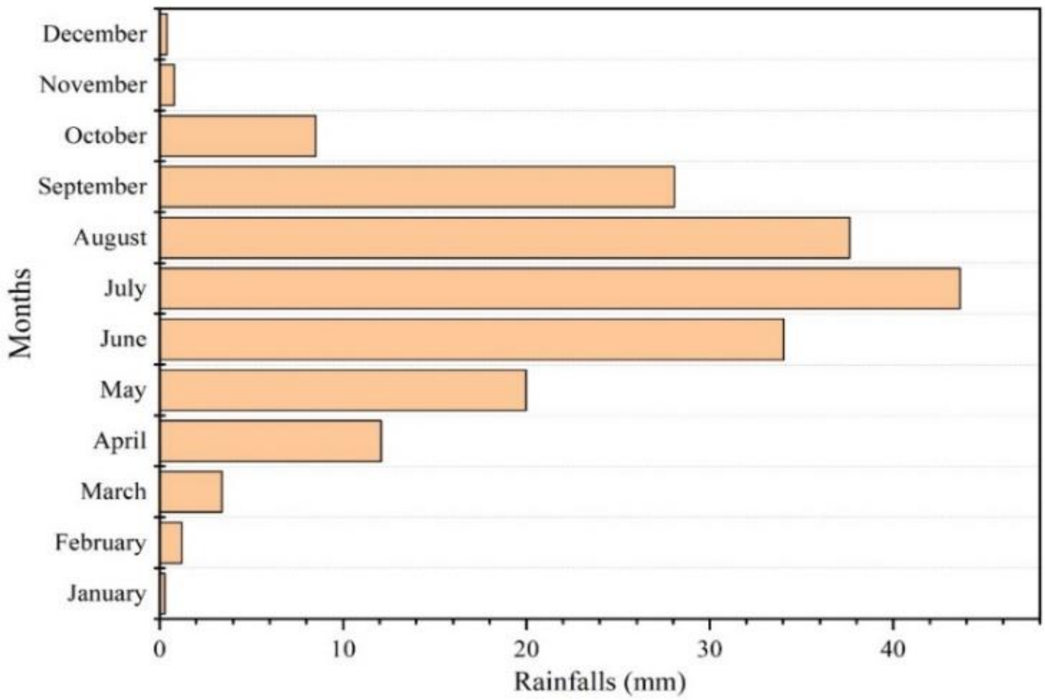

Fig. 4. Monthly Average Rainfall at Sunamganj Station (Station code: CL 127).

Rainfall in Sunamganj shows an increasing trend from January to July, peaking in April, May, and June (Fig. 4), which supports the safe harvest of Boro rice and planting of Kharif-I crops. However, the high rainfall during these months also causes frequent flash floods. In contrast, rainfall is minimal from November to January, leading to drought conditions that delay Boro rice planting and damage crops if planted during this period.

Haor water levels rise in the wet season due to river inflow and recede in the dry season as evaporation surpasses rainfall. Analysis of Surma River's monthly mean water levels (1993–2020) highlights these fluctuations (Fig. 5).

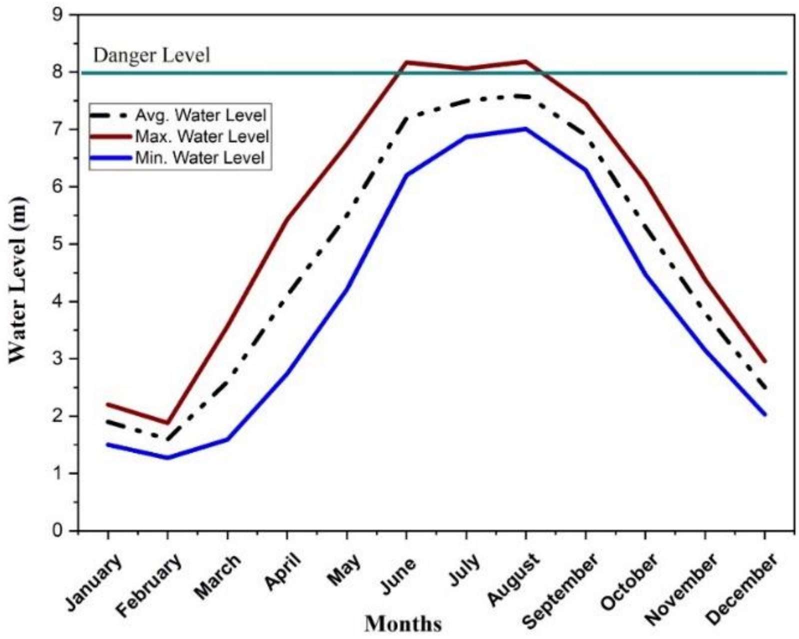

Fig. 5. Water level of Surma River at Sunamganj. Source: BWDB.

Analysis of water level data from the Surma River in Sunamganj district reveals significant variability, with levels ranging from 8.17 m to 8.18 m between June and August. Choudhury (2016) identified the July–September period as the high-flow season, often exceeding the danger level of 8.25 m PWD, while the November–April period is the low-flow season. The river's flashy nature, combined with concentrated rainfall and upstream runoff from areas like Cherrapunji, causes rapid surges in water levels, impacting regions like Tahirpur within hours, as observed by Jakariya and Islam (2017). Historical data from 1988 to 2016 reveal frequent breaches of the danger threshold during the monsoon, with notable floods in March 2015 and the catastrophic 2017 flood, which caused severe crop losses and embankment breaches. These recurring flood events underscore the urgent need for improved water management strategies and redesigned embankments to mitigate agricultural damage and enhance resilience in Sunamganj's haor regions.

The average discharge rate of the Surma River (station SW269) during nine years (2012-2020) is shown in Fig. 6.

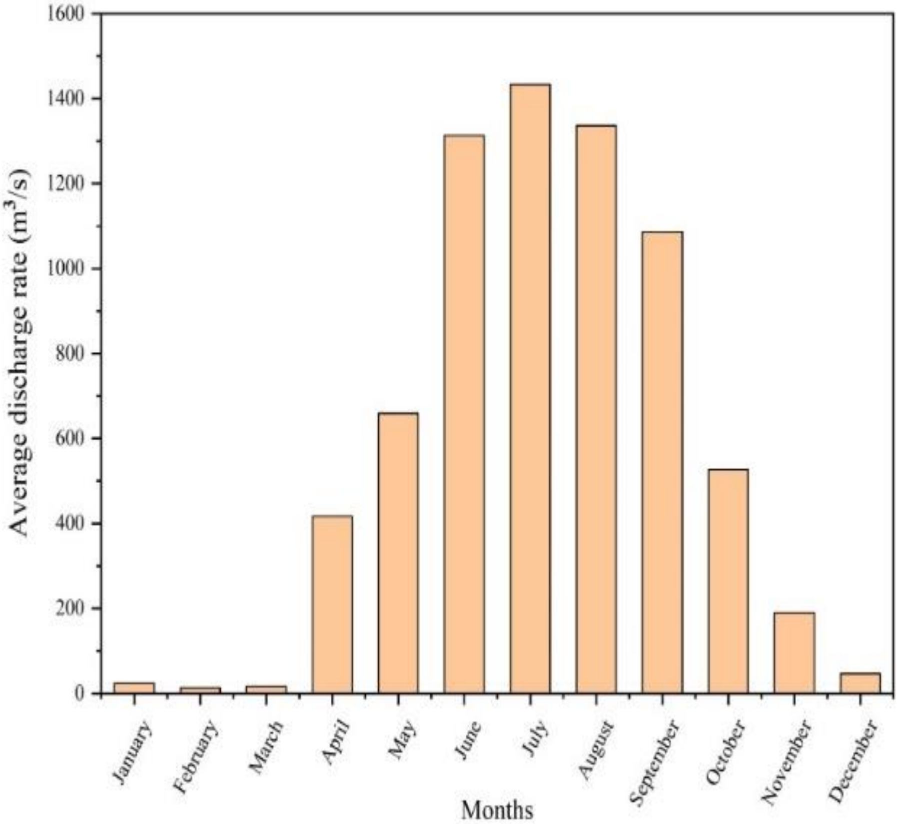

Fig. 6. Average discharge rate of Surma River (station SW269).

The average discharge rate is at its lowest from December to March. In April, the discharge rate exceeds 400 m^3/s, and it gradually rises until July, reaching a peak of above 1400 m^3/s, which is the highest of the year. It also provides evidence of crossing the danger level, as the average rate of discharge is highest from June to August. A geographic investigation (Rahman *et al*., 2018), found that rate of discharge (1623.50 m^3/s), which supports my study.

Cropping intensity and cropping pattern

Among all the haor areas of Sunamganj district, the proportion of the single-cropped regions is the highest (78.16%) in Jamalgonj. As a result, the cropping intensity in Upazila stands at the lowest (122%). In Tahirpur, the cropping intensity is about 154%. On the contrary, the proportion of triple-cropped area is the highest, with the lowest single-cropped area in Bishwamvarpur, resulting in the highest cropping intensity (171%), which is lower than the national average cropping intensity of 178% (Alam *et al*., 2010).

Table 3. Major Cropping patterns practiced in different Haor areas under study: 2021

Location	Cropping pattern	Area (ha)	% Area under the pattern
Bishwamvarpur	Boro-Fallow-T.Aman	4700	28.48%
	Fallow-T.Aus-T.Aman	1700	10.30%
	Vegetable-Fallow-T.Aman	1500	9.09%
	G.Nut-Fallow-T.Aman	450	2.73%
	Lentils-T.Aus-T.Aman	400	2.43%
	Soyabean-T.Aus-T.Aman	400	2.43%
	Watermelon-Aus-Fallow	350	2.12%
	Vegetable-Aus-T.Aman	200	1.21%
Tahirpur	Boro-Fallow-Fallow	14000	46.62%
	Boro-Fallow-T.Aman	6500	30.63%
	Vegetable/Aus/Jute/Sesame-T.Aman	2000	6.67%
	Boro-T.Aman-Mustard	1400	2.62%
	Aus-T.Aman-Robi crops	3020	12.26%
Jamalganj	Boro-Fallow-Fallow	20963	78.28%
	Boro-Fallow-T.Aman	3950	14.75%
	Robi vegetable-Kharif vegetable-T.Aman	153	0.57%
	Robi crop-Fallow-Fallow	893	3.33%
	Robi vegetable-Boro-Fallow-Fallow	863	3.22%

Source: DAE Field survey, 2021

The cropping intensity in the Haor area could be increased if efforts are made to improve irrigation facilities and adopt proper cropping practices for both single and double-cropped regions.

The existing cropping patterns in different haor areas reveal that in Bishwamvarpur, Tahirpur, and Jamalganj, the dominant patterns are Boro-Fallow-T. Aman (28.48%), Boro-Fallow-Fallow (46.62%), and Boro-Fallow-Fallow (78.28%), respectively. This indicates a reliance on single cropping, resulting in low crop intensity. However, other cropping patterns exist locally, highlighting the potential for diversification. In Tahirpur and Jamalganj, Boro-Fallow-Fallow covers 14,000 ha and 20,963 ha, respectively. Crop productivity remains low due to prolonged land inundation, except during the Boro season. To increase the cropping pattern in the Haor areas of three upazilas, irrigation should be developed on 10–40% of the kanda (ridge) land for Rabi crops, such as vegetables, pulses, and oilseeds. Short-duration crops, such as cauliflower, tomatoes, cucumbers, mung beans, lentils, onions, and garlic, can be grown on the edges of the haor. Meanwhile, floating beds can support crops like red spinach and coriander. Jamalganj has the highest single-cropped area (78.16%) and the dominant Boro-Fallow-Fallow pattern (78.28%), followed by Tahirpur in lowland extent. Floating bed farming offers a sustainable solution to enhance productivity and water management.

Conclusion

This study investigates the critical challenges of water management affecting crop productivity in the *haor* regions of Sunamganj, emphasizing the roles of land type, cultivable land, water usage, and hydro-meteorological dynamics. Farmers in this region primarily rely on surface or groundwater irrigation, with seasonal rainfall patterns exerting a significant influence on agricultural outcomes. Analysis of 37 years of rainfall data reveals that peak rainfall in July has rendered Aus crop cultivation impractical. Additionally, the Surma River exceeds danger levels from June to September, triggering flash floods that inundate fields and threaten crops. River discharge peaks in July, with a pronounced high-flow season from June to September and a low-flow season from November to April. During the monsoon, Haor water levels rise due to increased inflow, while the dry season is marked by reduced discharge and increased evaporation, resulting in lower water availability. The study highlights that floating bed farming could be a sustainable solution for submerged areas, enhancing productivity. Expanding this practice and improving stagnant water management could significantly boost cropping intensity. Integrating hydro-meteorological insights with local knowledge is crucial for developing resilient agricultural strategies in flood-prone Haor ecosystems.

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