An application of the participatory approach to develop an integrated water resources management (IWRM) system for the drought-affected region of Bangladesh

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Case report

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ABSTRACT

In many cases, poor management of water supplies is to blame for a crisis. Scholars and practitioners have proposed developing enhanced modalities of water governance that promote the implementation of Integrated Water Resources Management (IWRM) to meet the interconnected problems of assuring access to sustainable water supplies for the world's populations. Therefore, this research aims to do two things: 1) evaluate the current status of water and related resources, and 2) create an operational decision-support system for the sustainable use of water resources based on integrated water resources management (IWRM). Beneficiaries are involved in all stages of the planning process, from the first brainstorming to the final evaluation. There hasn't been anything quite like these kinds of efforts before because they do not actively include community groups and government agencies in project design and money distribution. Matching water resources with various users (farmers, fisherman, women, and others) and their agriculture and fisheries development requirements was the focus of this study, which took an integrated participatory approach. Therefore, water management agencies are established through participatory water management. Beneficiaries realized that collective action results in the empowerment of all community members through capacity building and participatory water management. Because of this plan, agricultural progress in the area under consideration will proceed smoothly.

1. Introduction

As populations grow and demand for improved living conditions increases, so does water use. Healthy ecosystems, thriving human populations, and stable economies rely on regular clean water access. Although poverty and its relation to water are complicated, many studies have shown a strong correlation between water provision and poverty alleviation [1]. Knowing whether a place is water-poor or water-rich is crucial for governments, river basin authorities, and development organizations to take appropriate strategic action in the name of adequate water resources management. Households and communities of varying socioeconomic statuses face unique conditions and problems that must be considered. Less water is available to the poor, and women's concerns are less likely to be considered or addressed (such as home water collection and privacy concerns related to sanitation) [2].

An integrated strategy is the most effective method when managing these essential resources. Several experts see this strategy as a good bet for ensuring the long-term viability of water resources management. Many things influence how effective this strategy is,

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however. For instance, the form and magnitude of emergent disputes, how they are resolved, and the relationships between water resource users and stakeholders, are crucial in determining integrated water resources management (IWRM) [3].

Regarding the justification for public participation, It is logical and valid that involving the public in the management of water resources enhances the possibility that "the public will accept a strategy." [4]." Consequently, the purpose of public involvement is to evaluate and manage by ensuring that decisions are influenced by the perspectives and experiences of those affected by them, (i) imaginative and innovative options are deemed ", and (ii) the provisions are workable and appropriate to the public. Better decisions and strategies, less disagreement, and easier enforcement are all outcomes that can be hoped for when people have a voice in the process. It promotes and facilitates social learning, contributing to a unified comprehension of water scarcity issues [5].

According to Dungumaro & Madulu, 2003, local communities should be involved in evaluating and resolving their water problems because they are the ones that interact with and have an impact on their ecosystems. The people in this situation understand what's best for them. Therefore, any initiative has complete support [6]. Therefore, this research aims to create an operational decision-support system for the sustainable use of water resources based on integrated water resources management (IWRM) and to draw some broad lessons regarding public participation.

There are two distinct ways to approach the Planning process. Both a top-down and a bottom-up strategy are possible [7]. People are encouraged to participate in growth activities through top-down planning rather than given the freedom to make their own decisions. This method often seems to make people reliant on the government. Bottom-up planning is the alternative method. URT's (2007) bottom-up analysis of PDP acknowledges that it can go in either of two directions: scenario one and scenario two. In the first case, participants use participatory tools to set objectives and plan courses of action. More importantly, it reinforces dependence. The second instance is when participants in the preparatory stage take charge and make choices. Imitative growth and the decisions and

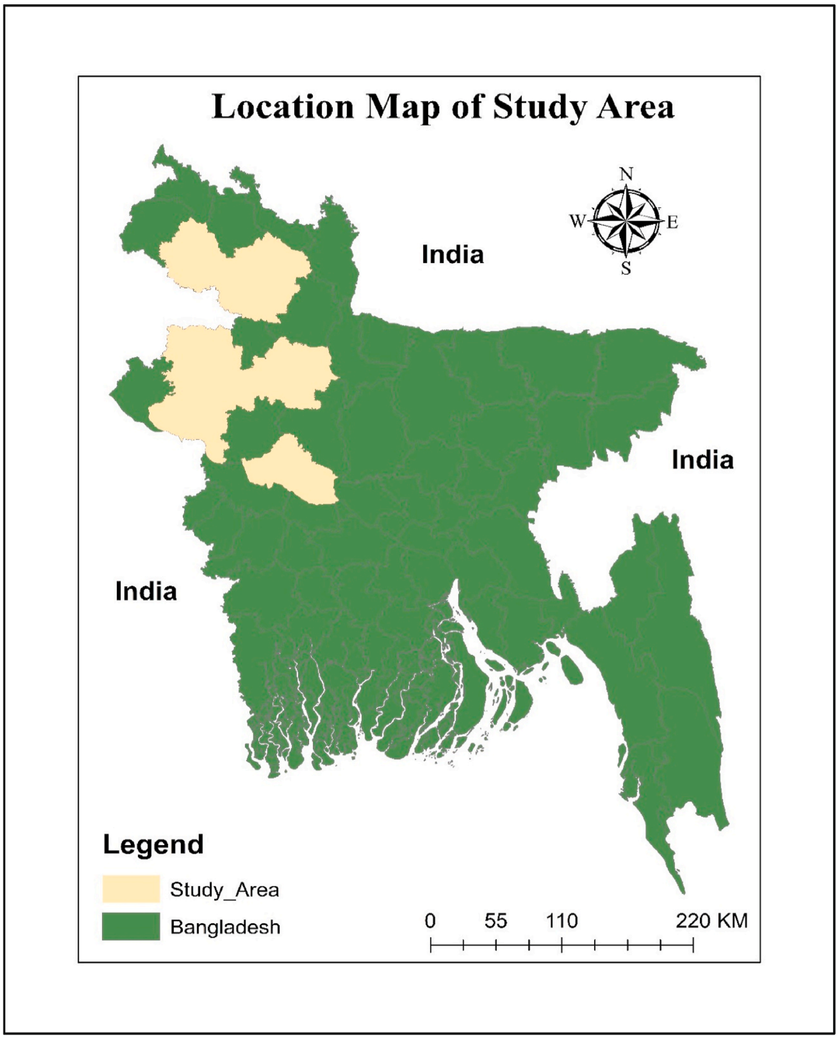

Fig. 1. Location Map of Study area.
Source: Prepared by Authors, 2021

resources that affect it can be shaped and shared by various parties through participatory decision-making (PDM). Stakeholders are given a voice and a sense of agency when they help set the operation's primary goals and contribute to its planning and execution [8].

Regarding urban planning, the paradigm of "Participatory Planning" emphasizes involving as many people as possible in decision-making. Some also include it in the process of developing societies. The goal of Participatory Planning is to involve members of the general public in the planning and design of a public area (where the public is identified as persons chosen by location and interest and as existing space users, as well as stakeholder organizations and experts and professionals) [9]. "Participatory Planning" refers to a sequence of steps to reach and implement an agreement among various stakeholders on a given idea. During the investigation and planning phase, the group can better communicate and consult each other on topics related to their development [10].

The origins of the term "integrated water resources management" are hazy, as with many other intellectual constructions. Each word is a generic, widely used term in planning and academic study. The requirement to grasp policy nuances is sometimes couched in terms of "integrated," which suggests that such an understanding is essential. Related concepts, such as "integrated planning," "integrated environmental management," "integrated risk management," and "integration into other policy sectors," are all near the heart of the definition of IWRM [11]. Words with similar meanings have become commonplace; some have faded while others have stayed put. An excellent method for managing this precious resource is an integrated strategy. Several experts see this method as a possible route to efficient and successful water management. In any case, the technique's efficacy is conditional on several conditions. The interactions between water resource users and stakeholders are also examined, although the existence and scale of rising disputes are the primary determinants of Integrated Water Resources Management (IWRM). Therefore, this research aims to provide a strategy for fostering integrated development and management of water and related resources to optimize economic and social welfare while guaranteeing equality and sustainability. Thus, the study's goals are (1) to evaluate the current status of water and related resources and (2) to recommend appropriate water resources management strategies for sustainable food production and area development [12].

2. The study area

2.1. Introduction

A drought is a complex natural period of dry weather and insufficient precipitation. When evaporation and transpiration exceed rainfall. Meteorological droughts are widespread, transient natural disasters [13]. A season's rainfall usually surpasses 25% of the long-term normal, and a more considerable deficiency signals a more severe drought [14]. The World Bank defines drought as an annual rainfall deficit of more than 30% compared to historical norms [15]. Drought is one of the most catastrophic natural disasters in the economy, agriculture, the environment, and society.

2.2. Description of the study area

Bangladesh frequently experiences floods, cyclones, droughts, and storms. In Bangladesh, droughts are often overlooked in favor of floods and storms [16]. Bangladesh has a drought when soil moisture levels fall below the threshold for optimal agricultural growth [17]. This slow-moving natural disaster can go unnoticed for a while. The research region (see Fig. 1) includes Rangpur, Bogra, Dinajpur, Pabna, Rajshahi, and Naogaon. 24° 07 minutes 7 seconds north to 24° 43 minutes 7 seconds east cover 4151.31 km^2 [18].

From a climatic perspective, the area experiences six distinct seasons: (1) the dry winter season (December–February); (2) the pre-monsoon hot summer season (March–May); and (3) the wet monsoon season (June–October) (Rashid 1991). The region's semi-arid climate is characterized by low and large precipitation variability. Annual precipitation averages 1400–1600 mm in this region, but other part of Bangladesh receives at least 2200 mm annually [19]. However, the area experiences a great deal of seasonal and interannual rainfall fluctuation, with the majority of precipitation occurring in concentrated bursts (June–October) and with slight variation in the average quantity of precipitation over the year [20]. Slight variation may be seen in the average rainfall. Therefore, there is always a risk of drought and water shortages, which seriously threaten agricultural output. Traditionally, rain-fed agriculture has played a crucial role in the rural economy and way of life. However, irrigated rice-producing area as a percentage of total farmland in the region has grown steadily over the past few decades. In this region, temperatures often hover between 25 and 35° Celsius during the warmest time of year and 9 and 15° Celsius during the coldest [21]. On the hottest days of summer, temperatures can reach 45° Celsius or higher here; in winter, however, the mercury can dip to a frigid 5° Celsius. Extreme heat and dry conditions are the norms in this region. There are places where the annual evaporation rate is less than or equal to the annual precipitation. Because of this, the weather in the northwest part of Bangladesh is typically described as nearly dry [22].

Agriculture is the sole industry in the area. 75% of the area studied is utilized for agriculture, with 31% monoculture, 56% intercropping, and 13% trellising. Approximately 59% of the area is used for agricultural irrigation, with nearly 75% of the water coming from groundwater. Unlike many other regions, the area under investigation rarely experiences flooding. As of this year, the agriculture industry in Bangladesh has used up 88% of Bangladesh's freshwater resources (35,870,000,000 gallons) [23]. The World Bank predicts a rise in droughts and water scarcity in Bangladesh, particularly in the northwest, due to declining and irregular rainfall. Since drought is the most common natural disaster in northwest Bangladesh, that region was chosen for this study. Water scarcity is a significant problem because agriculture is the primary source of revenue for the population [24].

2.3. Methodology to be adopted in the investigation

The extraction of waterbodies from satellite images has recently gained considerable interest. Various spatial, spectral, and temporal approaches have been developed to discern water bodies from diverse satellite images [25]. In the first stage of this research, remote sensing techniques are used to quantify the changes in the waterbody in the study area. This study uses Landsat imagery to characterize the spectral qualities of water bodies and other important surface features. Most initial remote sensor data consists of spectral bands with varied spatial resolutions. By determining the minimum value of the GSD (ground sampling distance), the spatial resolution of each band contributes to an increase in the level of precision achieved. The first step in image processing is gathering the photos, after which the layers are stacked. In image processing, layer stacking merges different picture derivatives with the exact spatial resolution. It generates precise output images that can be used for classification applications. A polygon feature was employed to mask the raster layer stacking dataset. Using the shape file of the drought-affected region of Bangladesh, the raster dataset utilized for classification was extracted. This work utilized unsupervised classification approaches to extract photos of aquatic bodies.

Training samples are not required for unsupervised classification; the requisite number of classes and iterations must be specified. The photographs were grouped into eight categories, then reclassified into two: water body and others. The primary objective of this study is to illustrate the change in the water body. The illustration depicts the extraction of the water zone between 1990 and 2020 (dry season) using unsupervised classification methods.

In addition, the study used several PRA tools for data collection to improve the administration of water resources and the mitigation of water shortages in the drought-stricken region of Bangladesh. Social and resource mapping, Venn diagrams, transect walks, timelines, problem and solution trees, cause and effect diagrams, and other Participatory Rural Appraisal (PRA) tools are used to assess the state of water resources and management systems in the study area. It was determined through a series of Focus Group discussions that a proper water resources management system was essential and that residents' preferences should be explored. The participatory approach aims to facilitate communication and understanding among all parties involved. Participation from a wide range of parties produces more helpful information for planning than would be possible from a concentrated effort by a single user group. Participatory Rural Appraisal (PRA) is a participatory planning method utilized in rural areas and government-led village projects [26].

2.4. What is Participatory Rural Appraisal?

An appraisal investigates previously gathered data regarding the challenges, opportunities, and potential outcomes. It is the first thing that needs to be done before anything else can be accomplished [27].

Participatory: A "bottom-up" approach, participation requires excellent communication skills and a positive outlook from project workers to keep people engaged in the process. Whether urban or rural, anyone can benefit from these methods [28].

A popular and valuable technique for gathering data in rural regions is the Participatory Rural Appraisal (PRA). The term "Participatory Rural Appraisal" (PRA) is used to represent a growing family of methods that aim to get people in rural areas to collaborate on gathering, analyzing, and acting on information about their own lives and environments [29].

- PRA is not widely understood as an approach or method in the local community. However, specific PRA methods have established linkages to regional community growth planning.
- PRA is an approach and methodology that encourages participation from the local community.
- PRA (Participatory Rural Appraisal) is an approach and set of tools for assessing community development initiatives with broad public input.
- PRP (Participatory Research and Planning) is a participatory approach and instrument that empowers local communities to conduct their development program research and planning projects.

The foundation of any PRA practice, regardless of its purpose or environment, is built on the following five principles:

At first, it incorporates community involvement which is crucial to the success of PRA because the method was designed to involve locals not just as data collectors but also as partners in the analysis process. Secondly, adaptability - The combination of appropriate methods in a given development context can be determined by factors like the size and skill mix of the PRA team, the time and resources available, and the subject and location of the work. Thirdly, collaboration: a PRA is most effectively carried out by a team comprised primarily of in-country experts (fluent in the target population's native tongue), supplemented by a small number of foreigners, a sizeable number of women, and, depending on the topic at hand, a blend of business professionals and social scientists. Fourth is optimal ignorance; PRA work aims to learn just enough to make the necessary suggestions and judgments efficiently and affordably. Since data generated by PRA is rarely suitable for statistical analysis, alternative methods have been created to guarantee the validity and trustworthiness of the results. Finally, systematic (given its primarily qualitative nature and relatively limited sample size). Many methods exist for analyzing public opinion on a single topic. They all entail some form of sampling and cross-checking based on some estimate of the population's stratification by geographical location or relative affluence (including through a final community meeting to discuss the results and correct Inconsistencies) [30].

Methods that are used in this study:

✓ **Social Mapping Process:** Group participants draw a visual map of the homes, important institutions (heads of the village, physicians, midwives, hospitals), and people's locations - shops, mosques, churches, rivers, transport hubs, assemble in the neighborhood.
✓ **Resource Mapping Process**: The participants draw a visual map where there are essential water-related structures.
✓ **Seasonal and Social Calendar:** Participants draw different crop patterns harvested during various seasons.

Table 1
Coordination Schema of the research work.

Objective	Required Data	Data/Tools	Reference
Assessment of the state of available water resources	• Deterioration of Surface Waterbodies	Landsat images for the dry periods of the years 1990 and 2020	
	• Water resources are available in the study area.	PRA- Resource mapping	
The proposition of a Participatory IWRM framework in drought or water scarcity management	• Frequency and extent of drought	Timeline	(Al-Qubatee et al., 2017)
	• Any significant changes include land use, amount of wetland, agriculture productivity, groundwater situation, and desertification in the study area.		
	• Water Use, most used source, why most used, quality satisfy or not	FGD	(Okada, 2016)
	• Understanding of the water scarcity problems, drought the preference and needs of local people to ensure an effective water resource management system	Focus Group discussions.	
	• The causes and suggested solutions of the water resources problems in the area from the part stakeholders' preferences	Problem and solution tree	

Source: Prepared by Authors, 2021

✓ **Time Transects Process:** Participants draw on how significant event related to drought and water resources management occurs their time on a timeline.
✓ **Problem Tree Analysis Process:** Group members draw a diagram of what causes those problems or circumstances.
✓ **Focus Group Discussion Process:** In a group, participants discuss a subject facilitated by a researcher with a record made by a note-taker.

After completing the tools mentioned earlier, the next step in this survey work is digitizing the maps created during the field survey for usage in a GIS environment (see Table 1).

Water inequalities and issues are discussed in depth during FGD sessions. And the new ideas that come out of the dialogue from the locals will be invaluable. The group comprises 10–12 individuals to ensure that all stakeholder groups are represented. The required number of participants per focus group ranged from three to twenty-one, with an average of ten [31]. Community groups established Resource Mapping to collect valuable data about residents' perspectives on water systems and related activities. The secondary data source is the compilation of records from the Bangladesh Bureau of Statistics (BBS), the Union Parishads (local administrative body), and the Department of Horticulture. Other essential materials were gathered from official websites like the Department of Agriculture, the Department of Horticulture, and non-governmental organizations (NGOs), all of which manage water supplies in the area under study.

3. Results and discussions

3.1. Changes in water area in the drought-affected region of Bangladesh

To assess the state of available water resources, the changes in surface water area have been identified during the period 1990 to 2020 (dry season) using the unsupervised image classification method. Fig. 2 represents that the amount of water area has decreased by 5.7% over the past three decades; one of the significant manmade reasons is the canals and rivers of this region are no longer receiving water after the construction of the Teesta barrage in India. Depending on the outcomes, the water body in the research area changed between 1990 and 2020. In 1990, most water features, including big ponds, Haor, Baor, the canal, and the river, carried enormous amounts of water. In 2020, however, the average size of the waterbody declined significantly.

3.2. Available water resources in the study region

Kursha is a union in the Taraganj Upazila of the *Rangpur* district with a total area of 23.679 square kilometers. The region's social and resource map comprises water features, farmlands, and rural infrastructures. Eight ponds are used in fish farming operations, while three deep tube wells and seventeen tiny tube wells supply irrigation. However, in the dry season, only one DTW remains effective, leading to an additional cost for irrigation. For storing rainwater for use in irrigation during the dry season, some farmers have re-excavated ponds that are not sufficient in number. Dairy farming is not attractive to farmers due to the combined factor of high labor costs and low prices for consumer goods, the absence of grazing areas, and susceptibility to diseases of the cattle due to harsh weather. The area suffers from double disaster against agriculture: drought on an annual basis damaging crops and flood washing off the crops. However, Table 2 shows this region's changing trend of irrigation patterns. In the past 10–15 years, people had a significant dependency on minor drains for irrigation water, which has vanished entirely due to a lack of careful administration of such sewers. The Dalia irrigation project began in the region in 2010. The lack of water in the Tista River ultimately doomed this operation and its

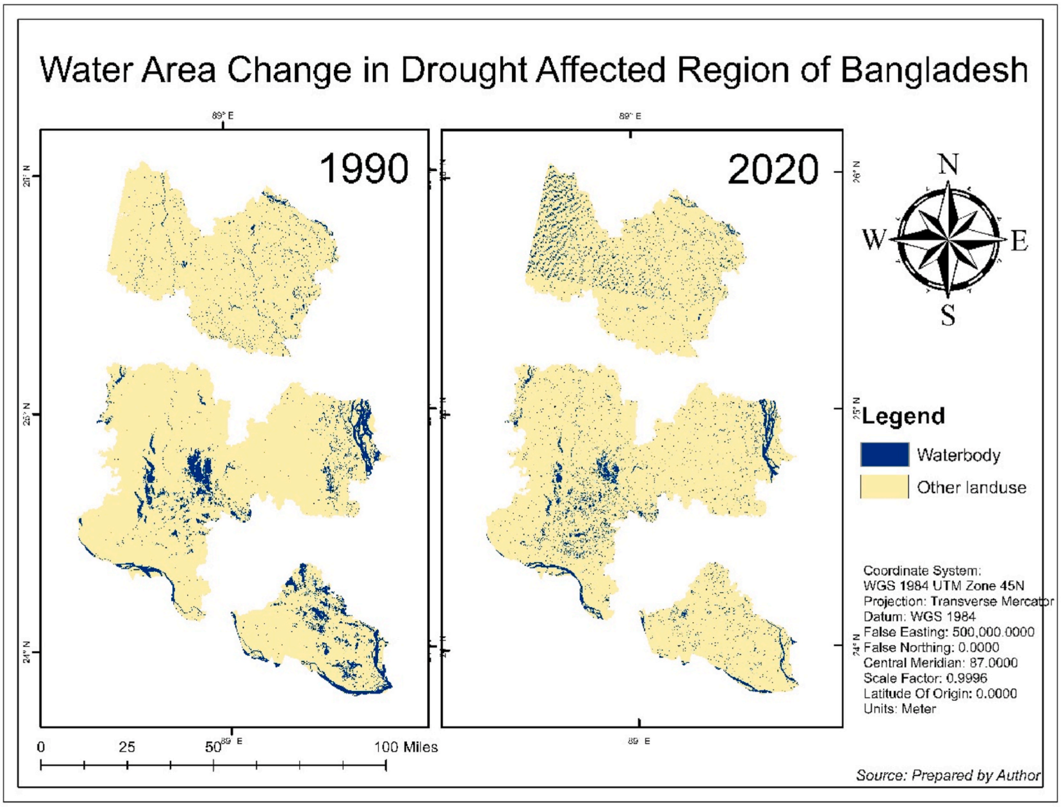

Fig. 2. Change in water area in the study area.
Source: Prepared by authors, 2021

Table 2
Timeline of Kursha, Taragonj, Rangpur community.

Time	Important events	Remarks
1990	Use of Tube well, pond and rain water	
1994	Deep Tube well by BMDA	Fish distinction
2003	Started to grow double rice	Previously grew only one rice crop
2004	Pump of BMDA became unfit	Less agricultural activity.
2005	Construction of Small drain.	Farmers were successful
2008	Drought	Number of farmers decreasing.
2009	Construction of Brick Kiln	Land shrinking because of construction.
2010	Dalia Irrigation Program	Increased production rate
2011	Started to grow rice, paddy, potato	Growing upland crop
2012	Lease of pond	No chance of using pond
2014	Establishing Personal Pump/machine	Better irrigation
2016	Establishment of Small Cottage Industry	Better income
2018	Establishment of Shoe factory	Less availability of agricultural worker.
2020	Drain became unfit	Growing upland crop

Source: Field Survey, 2021

associated project. Nowadays, irrigation is accomplished using both personal pumps and deep tube wells. However, the high price of utilizing these options has caused a shift in occupation. When people saw that agriculture was not yielding enough money, they resorted to constructing brick kilns, cottage businesses, and shoe factories.

In the *Pushpopara* village of *Pabna,* water sources include seven ponds, two deep tube wells, and fourteen small tube wells. According to the historical timeline shown in Table 3, farmers in this region typically employ tube wells and shallow machines. This region has experienced a drought lasting four to five months every four to five years. At least 15 droughts have hit this region in the past 30 years. The government installed a deep tube well in 2008 for agricultural use, which is currently being maintained and administered by the local community. In addition, a community group purchased a deep tube well. Sometimes the drought lasts a more extended period, even up to five months, that impacts the irrigation system adversely. Many people in this region have started adapting

Table 3
Timeline of Pushpopara, Pabna community.

Time	Important events	Remarks
1992	Use of Tube well and pond	
1997	Deep Tube well by BMDA	Fish distinction
2002	Started to grow double rice	Previously grew only one rice crop
2001–2003	Regular rain season wise	Farmers were successful
2004	Drought	Less Production in Agriculture
2004–2005	Starting of imbalanced rain	Less production
2005–2006	Drought	Less Production in Agriculture
2007	Pump of BMDA came	Increased production rate
2008	Started to grow triple rice	Growing upland crop
2009	Lease of pond	No chance of using pond
2010	Pump of DASCOH	Better irrigation
2012	Beginning of vegetable cultivation	Better income
2014	Drought	Less income in agriculture
2016	Pump of BMDA became unfit	Growing upland crop
2019	Cultivating dragon fruit	Need less irrigation

Source: Field Survey, 2021

the lean agricultural work by cultivating rabi crops in the dry period, working in rice mills, and shifting their job.

Haripur, a small village in *Mohadevpur, Naogaon,* is rich in natural resources such as abundant farmland, five ponds, two deep tube wells, and seventeen shallow tube wells. Table 4, the historical timeline, shows that in 1990, an underground drainage system with natural water sources formed the backbone of this region's irrigation system. Barind Multipurpose Development Authority (BMDA) first took initiatives to assist the farmers with the inadequate water flow in 2003 during IRRI cultivation. When taking water from private pump owners, the farmers have to exchange one-fourth of their crop with water. Many farmers are now using an "alternative crop production" strategy to combat water scarcity and increase agricultural income. Mango gardening is more profitable than rice farming and requires less water and human resources. During Aswin, Kartik, and Falgun-Chaitra, rural unemployment is exceptionally high due to water scarcity and intense heat that results in seasonal migration.

Vetupara village is situated in, Mohanpur, Rajshahi. Although there is land abundance in this village, the farmers face double disasters due to the Teesta dam: lack of water in the dry season and floods during the rainy season (see Table 5). The historical timeline shows that BIADP installed the first DTW in 2003, increasing the cropping frequency three times. The pumping system has developed since BMDA started installing DTW in 2010. But, due to being diesel-operated, BMDA-provided wells cost higher Maintenance. Now, there are three deep tube wells and twenty shallow tube wells for irrigation used for irrigation, but the shallow ones get dried in the dry season. The government dug a few canals for irrigation service, which also dried in the dry season. Therefore, many farmers feel interested in orchard and fish farming.

3.3. Cropping pattern in the drought-affected region of Bangladesh

The most common schedule for planting crops in the area is depicted in the figure above (see Fig. 3). It compiles a list of the six most important crops grown in each town and ranks them according to the planting season and the specific water needs of the crops. The

Table 4
Timeline of Haripur, Mohadevpur, Naogaon community.

Time	Important events	Remarks
1990	Use of Natural sources	No Water Shortage
1996	Earthen (Kacha nala) system for water supply.	Less water and Blockage.
2001	Drought	Food shortage.
2003	Irrigation water supplied by BMDA	The water is supplied in Kartik and Agrahayon at the time of implantation IRRI in their field.
2007	Local pump owner group	Farmers have to sacrifice one fourth of their product to the pump owner.
2009	Irrigation water supplied by BMDA	The water is supplied in Poush, Magh, Falgun at the time of implantation IRRI in their field. But earlier it was observed in Kartik and Agrahayon. This difference is occurred because of the change of cropping pattern with time.
2013	BMDA provides less water consuming seeds	The cropping pattern has become Paddy-dependent due to availability of various type of hybrid paddy seed.
2015	At re-excavated khals/Kharies, water holding structures such as cross dams (submerged weirs) and rubber dams are built to conserve rainfall.	BMDA should build this type of structure more.
2018	Buried pipeline instead of earthen drain by BMDA.	The amount of water lost, the expense of irrigation, and the amount of land lost have all been decreased.
2020	People start to suffer from food shortage in choitra and Baisakh due to slack season	People start to seasonally migrate.

Source: Field Survey, 2021

Table 5
Timeline of Vetupara, Mohanpur, Rajshahi community.

Time	Important events	Remarks
1990	Use of Natural sources	No Water Shortage
1994	Less water in the canal	Single Crop season
2003	Installing Deep Tube Well (DTW) through BIADP.	Single cropped land has been converted into three cropped land.
2005	Personal pump for irrigation	Use of both ground water and surface water.
2007	Diesel powered irrigation system	High maintenance cost.
2010	DTW by BMDA started spread over the area	Change in cropping pattern. Rice started to grow twice in a year in the covered area. People started to grow potato, maize in lieu of mustard.
2014	BMDA electrified the DTW and used a submersible pump to replace the diesel engine.	Less maintenance cost.
2016	Started fishing in commercial way	No chance of using pond for agricultural purpose.
2019	Fishing become attractive	People started fishing instead of cultivating crops.
2021	Almost all areas covered by DTW	Because of ground water depletion people stopped using shallow machine.

Source: Prepared by Authors, 2021

frequency at which each crop has to be irrigated determines the ranking order of its water requirements. However, except for the Mohadevpur Upazila, the region's low water demands have contributed to the rise in popularity of winter-based rabi crop production. It differs from the conventional cropping method, paddy. A significant amount of drought is prevalent in Mahadevpur and typically starts in March. As a result, the BMDA provides irrigation water in the Kharif-1 season while the Aus paddy is planted in their field. Amon paddy is the only crop the farmers can grow to keep their livelihoods because it has a low water requirement and is nourished by the rain.

On the other side, the unfavorable effect that the drought has had on the irrigation system in Pabna, Rajshahi, and Rangpur has been balanced by the positive effect that the installation of Deep and Shallow tube wells has had. As a consequence of this, farmers are planting their crops during all three of the previous seasons: Kharif-1 (Aus), Kharif-2 (Amon), and Rabi (Boro). Even though hybrid Boro paddy is produced, meeting the greater water need of Boro paddy is unaffordable for low-income and marginal farmers. The bother of interrupting water supply during the dry season due to groundwater depletion can be reduced through transitioning to rabi crop farming which is another advantage of making the switch. However, depending on factors like soil type, availability of hybrid seed, and consumer desire, the crops planted might vary widely from one town to the next. For instance, due to the lucrative output that ginger cultivation can provide, the Department of Agricultural Extension in Rangpur (by way of providing necessary training and the most recent technologies) and commercial banks in Rangpur (by way of providing easy-term agriculture loans) are working together to promote ginger cultivation in the region. Consequently, many farmers are switching their focus from paddy production to ginger production during the Kharif-1 season.

In contrast, the cultivation of maize is outpacing the cultivation of wheat and Boro paddy in Rajshahi. The average cost of producing maize is almost four times lower than wheat, and the high water need for Boro paddy also plays a role. To summarize, the type of crops grown in any given region heavily relies on the type of irrigation water system already in place, its supply system, price, and availability time.

3.4. Problems associated with water resource management and probable solution to those problems

Drought has become a common hostile phenomenon in the Barind Tract of Bangladesh, disrupting their farming practice (principal economic activity). Due to the lack of precipitation, soil moisture levels drop, and surface water becomes scarce. The water scarcity is creating a countless impact on the livelihood of farmers, including the water inadequacy for irrigating their preferred crops (high-yielding Boro, Jute), disturbing the actual yield of crops (wheat, pulse, potato, sugarcane, aus, and aman) and even crop failure in extreme conditions. The low availability of water resources with a greater demand also underpins strife among the farmers, which leads the wealthy farmers to be more benefiting than the marginal farmers. The collective factors include water stress, interrupted farming activity, poverty, and crop failure. Therefore, farmers are pushing towards migration as the only option for living (see Fig. 4).

On the other hand, the surface water paucity is generating a countless pressure on the groundwater to meet the minimum irrigation demand and domestic demand, which in turn leads to a drastic depletion of water levels in this region. Albeit it is impossible to transform the geologic formation and climatic occurrence, taking proper adaptation measures to reduce the severity of the disaster. Firstly, the participatory water management practice and mutual assistance among farmers can effectively minimize the adverse impact of water scarcity. Secondly, it becomes necessary to bring advancement in the existing farming practice through fostering the use of drought-resistant crops, organic fertilizer (reduces the water loss through runoff and percolation and allows the soil to hold water), mixed cultivation (concurrent use of the same land for more than one crop brings more profit by consuming less water) and shift to the farming of low water-intensive rabi crops. Finally, investment in surface water harvesting projects, such as re-excavating ponds and canals and constructing cross dams and reservoirs, can also have the scope to convey a long-term solution for reducing the hardship of the people in this arid region.

4. Institutions working in the drought-affected region of Bangladesh and their relationship

One of the useful PRA tools, the Venn diagram, is used in the study to explore the relative importance of the water supplier

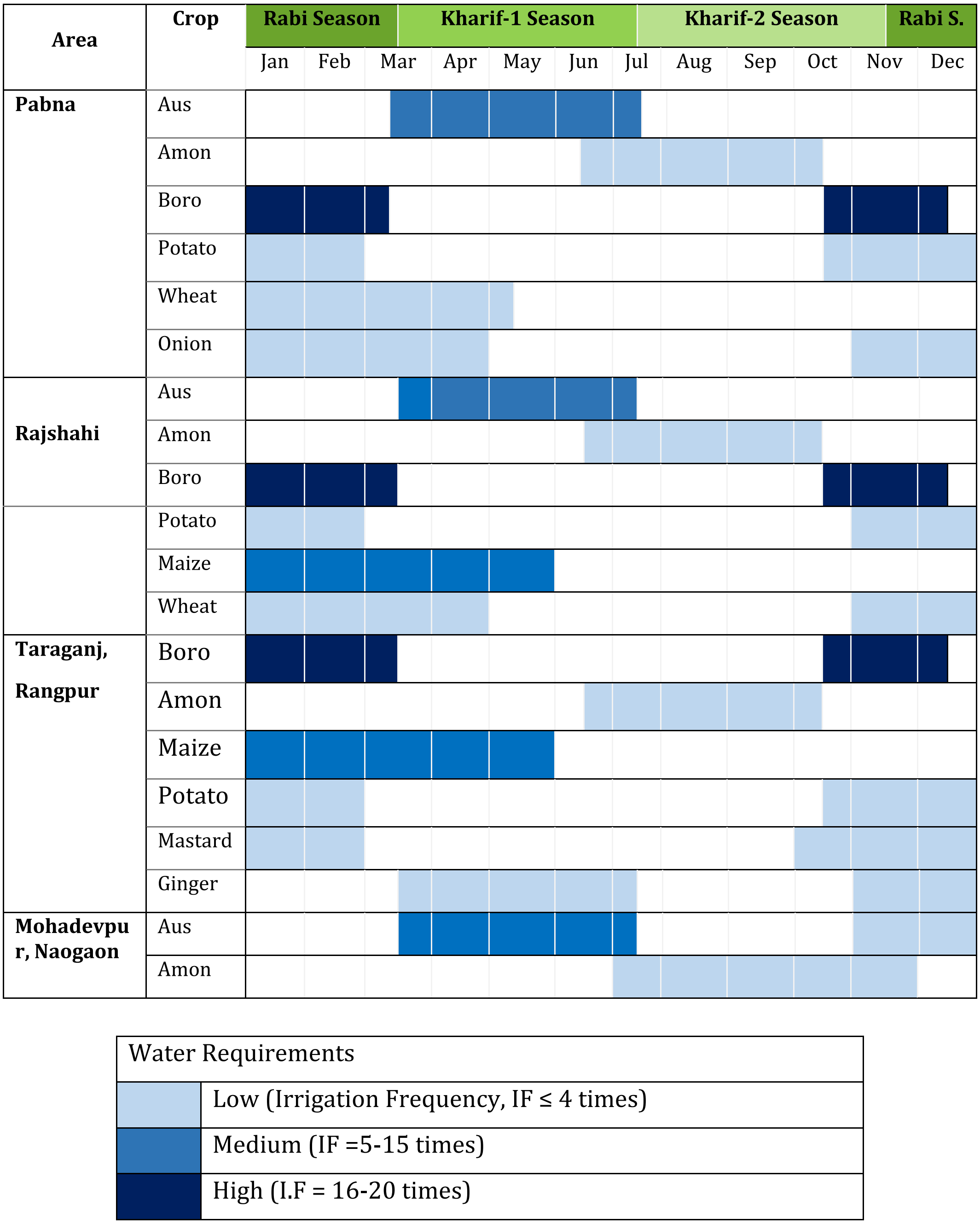

Fig. 3. A comparative picture of the 'Crop Calendar' among the study Communities.
Source: Field Survey, 2021

organizations (both direct and indirect) in the study region. As shown in Fig. 5, two governmental agencies: *BMDA* and *BADC,* play a crucial role in the irrigation system in the area. BMDA, operating under the Ministry of Agriculture, is primarily accountable for the growth of the Barind tract. It provides water pumps and bottomless tube wells with lower interest rates and assists with installing tube wells. In contrast, BADC offers the farmers some rudimentary irrigation facilities. As installing tube wells is too expensive for the poor farmers, several *financial institutions,* including *BRAC, ASA, Ananya, CBSDP, Grameen Bank, Proshika, Odhora, and Protisruti* assist the farmers directly or indirectly by providing loans for agricultural endeavors. Some *pump owners* provide water to the farmers, but the cost is comparatively higher than BMDA. *The local market* also influences the water supply by selling shallow machinery and installation equipment. Since these institutions and organizations do not share a direct connection, the graphic does not feature any overlap between them, yet, they are all equally important.

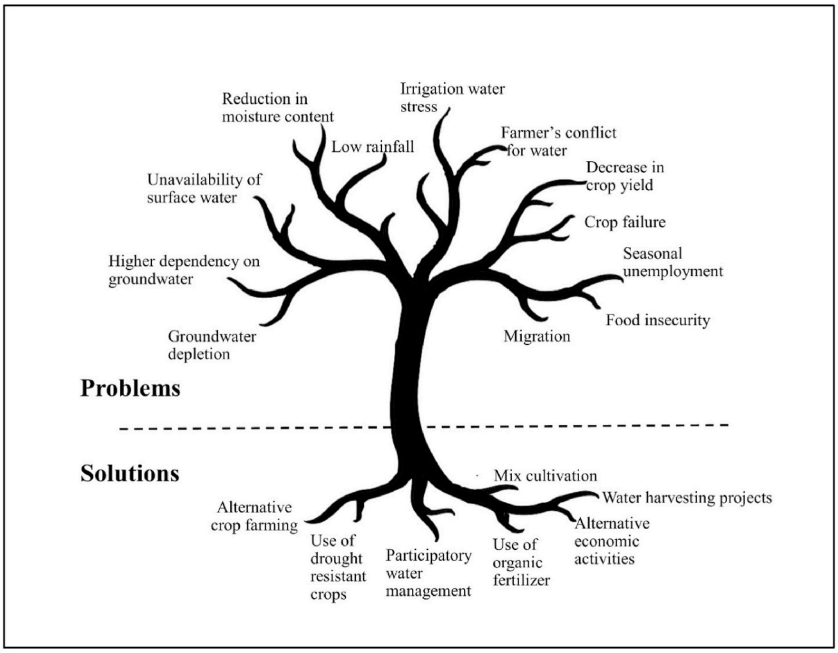

Fig. 4. Problem and Solution Tree for the drought-prone region of Bangladesh.
Source: Field Survey, 2021

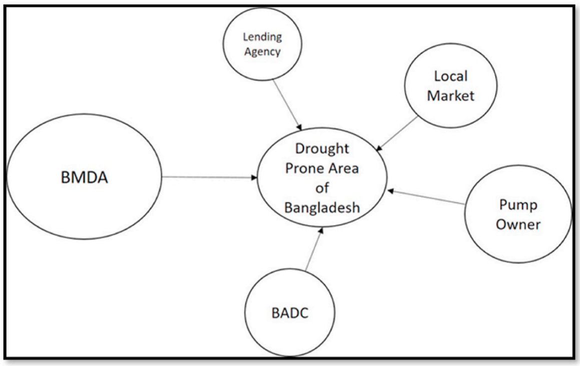

Fig. 5. Venn diagram of stakeholders.
Source: Field Survey, 2021

4.1. Recommendations

From its beginning to its end, the water management program in this region must incorporate every farmer or representative. Experiential learning makes members more invested in the process, which is good for community growth and success.

Mapping water resources with a Geographic Information System (GIS) and satellite data are examples of cutting-edge technology that should be employed to gain insight into the water management system, including assessing existing water resource potential. It is not enough for humans to "find water," "flow direction of water," "preserve water," and "effectively manage water" they must also recognize the societal contexts in which these activities take place. The community now has more information, leading to improved water management and planning. The results of this study on land use classification show that river erosion and siltation are causing water bodies to shrink and change shape and size. Because of this, there are often floods and long-lasting droughts. Flood, river erosion, and river siltation must be managed on both the central and local rivers, and this requires extensive modeling and GIS application. The river must be trained partly through dredging and the other through other means.

The distribution of water resources, local monitoring, the establishment of rules for the routine use of water, and the development of a management system with explicit norms and regulations are all examples of activities in which community members can be involved as part of an implementation of community-based water resources management (CBWRM). With CBWRM, local water users are included in water resource management, and water's monetary value and cultural significance are acknowledged. Well-established, yet room for enhancement exists in the community management of the region's existing water resources. Any infrastructure for storing or delivering water owned by the community must be managed effectively. Politically-inclined locals typically oversee government-supplied deep tube wells. And unfortunately, those who have been granted control of such a water structure can occasionally abuse their position of responsibility. Some farmers have easy access to water, while others are discriminated against. Bangladeshi farmers in the afflicted region are hoping for more accurate drought reports. Some must spend more money than they should to obtain water for farming purposes. Solving this problem will require precise local monitoring of water supply and demand to achieve a sustainable equilibrium. To the extent that they exist, larger management systems can be supplemented by community-based organizations to better track rainfall, groundwater fluctuations, and communal absorption, negotiate water allocations and establish operational standards for water use.

The region under investigation thus has a management-related issue. In the eyes of the stakeholders, this was a crucial part that required additional work. The experiences of other developing nations can be applied (for example, Sungai Lar River Basin, Malaysia). In Malaysia, the Sungai Langat River Basin falls under the purview of the Selangor Waters Management Authority (SWMA), an agency of the Selangor State Government. The SWMA regulates water abstraction, issues licenses, and enforces water allocation. This model of assigning water and water infrastructure management responsibility to a single, central agency is instructive and replicable. And the members of this group need to be open about their deliberations and answerable to the general public. Representatives of the local community should be included in this body.

In addition, most of BMDA's current water management system and projects focus on groundwater. This approach to problem-solving is unsustainable in the long run. The water conservation plant can potentially be an improved and long-lasting answer to the issue of water scarcity in the research area, as it can collect and store both floodwater and rainwater. Some such structure is discovered in the research. The locals believe that the Maintenance is poor, and they also believe that the facilities themselves are lacking.

People in the area have also pointed to India's dam construction as the primary cause of the drought and water shortage there. The government of Bangladesh might take action similar to the Nile Basin initiative to address the issue. The Nile Basin Initiative is the product of a "shared vision" strategy that prioritizes equitable distribution of the benefits to the riparian countries as a consequence of their joint efforts to develop and manage their water resources rather than on sharing water itself. Consistent with IWRM principles, the Shared Vision Program trains stakeholders to collaborate on transboundary natural resource management, divide up the spoils, and increase water efficiency in fields like agriculture. Long-term action plans based on a shared vision have been developed using processes similar to those in the Lake Chad and Niger basins.

There is currently no evidence of private sector involvement in water resources management in this area. The water resources management system in the drought-stricken region of Bangladesh might be drastically improved by encouraging private sector involvement in the field and establishing a megaproject. There should be proper institutional links. Projects frequently fail due to institutional disputes.

4.1.1. Recommendation from focus group discussion

Most of the time, cleaning and repairing canals are done as part of the system's operation and Maintenance of the system. The nature of these activities is that they are preventative. This operation, which takes place right before the start of the monsoon season, comprises cleaning the area of any garbage that may be floating, as well as water hyacinth, grass, and weeds. This process takes place immediately before the monsoon season begins. In addition to this, it is an unavoidable requirement that routine maintenance is performed on the canals. This continual Maintenance entails various tasks, including re-excavating canals and preventative Maintenance on other water system components. The final step entails various maintenance tasks, including lubricating, cleaning, and painting the water infrastructure. Members of the water maintenance organizations responsible for the facilities could perform efficient Maintenance on those facilities because the project offered training in correct care that was delivered to those members of the water maintenance organizations—the completion of the project allowed for this to become a reality.

Discussion in FGD also identifies a further difficulty in the current budget situation. Lack of funding put an end to many promising projects. Step by step, the government should rely less on external funding and more on domestic sources. Helping women out of their current predicament requires a strategy considering all relevant aspects. For instance, it would be beneficial to include women in the conversation about water and actively listen to what they have to say. A solid groundwork for women's issues in water-related organizations and policies can also make this a reality. In conclusion, achieving the IWRM principles can be aided by the equitable distribution of water resources across sectors to promote economic growth while also considering poverty reduction and environmental sustainability objectives.

5. Conclusion

Communities often fail to address crucial issues of environmental management. Long-term sustainability in water management can only be attained through collaborative community water resources management. It is especially true if government resources are limited or people choose to avoid legal assistance. Over the past two decades, there has been a lot of focus on Integrated Water Resources Management (IWRM) to manage countries' water supplies better. This research assessed the water management practices and infrastructure already in place in the drought-stricken region of Bangladesh. The study also looked into methods and ideas put forth by locals to better the region's water management infrastructure. The research suggests that sustainable development in community water resources management requires cooperation between government agencies and communities, especially those operating at the local level. In general, the community management of the area's water resources is effective, but there is room for improvement.

Any infrastructure for storing or delivering water owned by the community must be managed effectively. Politically inclined locals typically oversee government-supplied deep tube wells. Farmers with more money receive benefits, while those with less fall further into poverty. In extreme circumstances, crop failure can occur due to prolonged lousy water situations. The combination of scarce water, a halt in farming, economic hardship, and failed harvests is to blame. They're pressuring farmers to leave their homes for better economic opportunities.

Conversely, the severe depletion of water levels in this region directly results from the constant strain that the surface water scarcity is putting on the groundwater to meet the minimal irrigation demand and domestic needs. Adaptation methods can lessen the impact of a disaster even when it is impossible to change the underlying geological structure or the climatic occurrence that caused it. The adverse effects of water shortage can be mitigated by adopting participatory water management practices and providing mutual aid among farmers. Second, it's essential to promote the use of drought-resistant crops, organic fertilizer (which cuts down on water loss via runoff and percolation and makes the soil better able to retain water), mixed cultivation (which uses the same land for multiple crops at once, maximizing profit while decreasing water use), and the transition to the farming of low water-intensive rabi crops. Finally, investments in surface water harvesting projects like re-excavating ponds and canals and building cross dams and reservoirs can potentially provide a long-term answer for easing the burden of the inhabitants in this arid region.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

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