Pre-feasibility study report

Extended Community Climate Change Project-Drought (ECCCP-Drought)

Palli Karma-Sahayak Foundation (PKSF)

Contents

Abbreviation

AE	Accredited Entity
AEZ	Agro Ecological Zone
AMSL	Average Mean Sea Level
BADC	Bangladesh Agricultural Development Corporation
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BCAS	Bangladesh Centre for Advanced Studies
BCCRF	Bangladesh Climate Change Resilience Fund
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BCCTF	Bangladesh Climate Change Trust Fund
BDT	Bangladeshi Taka
BGL	Below Ground Level
BIADP	Barind Integrated Area Development Project
BINA	Bangladesh Institute of Nuclear Agriculture
BMD	Bangladesh Meteorological Department
BMDA	Barind Multipurpose Development Authority
BRRI	Bangladesh Rice Research Institute
BWCSR	Bangladesh Weather and Climate Services Regional Project
BWDB	Bangladesh Water Development Board
CCA	Climate Change Adaptation
CCAGs	Climate Change Adaptation Groups
CCCP	Community Climate Change Project
CDD	Consecutive Dry Days

CDMP	Comprehensive Disaster Management Programme
DAE	Department of Agricultural Extension
DAE	Direct Access Entity
DC	Direct Current
DJF	December, January, February
DoE	Department of Environment
DoL	Department of Livestock
DPHE	Department of Public Health Engineering
DRR	Disaster Risk Reduction
DTWs	Deep Tube Wells
ECCCP	Extended Community Climate Change Project
EE	Executive Entity
ERD	Economic Relations Division
FAO	Food and Agriculture Organizationof UN
FAP	Flood Action Plan
FYP	Five Year Plan
GCF	Green Climate Fund
GUK	Gram Unnayan Karma
GWL	Ground Water Level
GWT	Ground Water Table
HBT	High Barind Tract
HH	Household
HRLS	Human Rights and Law Support
IDCOL	Infrastructure Development Company Limited
IEs	Implementing Entities
IWRM	Integrated Water Resource Management

JJA	June, July, August
LACC	Livelihood Adaptation to Climate Change
LDC	Least Developed Country
LGI	Local Government Institute
MAM	March, April, May
MAR	Managed Aquifer Recharge
MoA	Ministry of Agriculture
MoDMR	Ministry of Disaster Management and Relief
MoEF	Ministry of Environment and Forests
MoEFCC	Ministry of Environment, Forests and Climate Change (MoEF was recently renamed as MoEFCC)
MPO	Master Planning Organisation
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action
NDA	National Designated Authority
NEMAP	National Environment Management Action Plan
NGOs	Non-government Organisations
NTIWG	National Technical Implementation Working Group
NWMP	National Water Management Plan
NWPo	National Water Policy
O&M	Operation and Maintenance
PDF	Probability Density Function
PET	Potential Evapotranspiration
PKSF	Palli Karma-Sahayak Foundation
PMU	Project Management Unit
PO	Partner Organisation
PP	Perspective Plan

PPP	Purchasing Power Parity
RBM	Results Based Monitoring
RIC	Resource Integration Centre
RTE	Real Time Evaluation
RWH	Rain Water Harvesting
SAP	Simplified Approval Process
SEMP	Sustainable Environment Management Programme
SI	Seasonality Index
SMF	Social Management Framework
SPEI	Standardised Precipitation Evapotranspiration Index
SPI	Standard Precipitation Index
TEC	Tender Evaluation Committee
TIWGs	Technical Implementing Working Groups
TNC	Third National Communication
UK	United Kingdom
UND	United National Development
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
VERC	Village Education Resource Centre
WARPO	Water Resources Planning Organisation

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1 Introduction

1.1 Context of the pre-feasibility study

The GCF's Simplified Approval Process (SAP) is an opportunity for Least Developed Countries (LDCs), Small Island States and African countries and particularly for Direct Access Entities (DAEs) to obtain climate finance from GCF. This process requires less documentation as well as less time to receive GCF support. Palli Karma-Sahayak Foundation (PKSF) took the opportunity in order to achieve a transformational shift towards community's resilience through establishment of systemised approach measuring effectiveness of adaptation interventions, capacity of local and national institutions and demonstrations under this process. Being a DAE of Bangladesh, PKSF is responsible to enhance the country's access to GCF for building a climate resilient society particularly at the community level. In this context, PKSF has been developing proposals based on country's priority for getting access to GCF fund through SAP mechanism. Presently, the Foundation is preparing a project proposal titled "Extended Community Climate Change Project-Drought (ECCCP-Drought)" under the Simplified Approval Process (SAP) mechanism of GCF. The pre-feasibility study is an important part of the project proposal.

This project is based on PKSF's experience and learning from the implementation of the Community Climate Change Project (CCCP), which was funded by the Bangladesh Climate Change Resilience Fund (BCCRF). The CCCP was a successful project and contributed significantly to the increased resilience of the climate vulnerable communities in the country.

CCCP was a project implemented in coastal, flood and drought prone areas of Bangladesh. In order to implement adaptation activities at the larger drought prone regional scale, it is essential that the most effective set of adaptive interventions are identified and delivered at the community level at a wider scale efficiently. The CCCP has demonstrated the efficient mechanism of implementing community-based adaptation projects. Taking best practices and lessons learned from the CCCP project together with an innovative evaluation and dissemination design, PKSF has developed the Extended Community Climate Change Project-Drought (CCCP-Drought), to increase resilience to climate change induced drought 215,000 people in the selected three districts namely Rajshahi, Chapainawabganj and Naogaon by doing so demonstrate how scaling up of drought resilient interventions can be achieved both efficiently and effectively for the entire drought prone region of Bangladesh.

1.2 Objective of the Pre-feasibility study and Methods

The objective of the study is to examine feasibility of the proposed project in the context of adaptation needs and priorities of the drought vulnerable communities of the country. The study also examines national policy related to climate change issues to ensure country ownership. Finally, the study will recommend effective adaptation options for the drought affected community.

The pre-feasibility study report has been prepared mainly based on the secondary data, *i.e.*, literature review and consultation process. The literature review includes National Communications of Bangladesh submitted to UNFCCC, Bangladesh Climate Change Strategy and Action Plan (BCCSAP), 2009; National Adaptation Programme of Action (NAPA), 2005, revised 2009; Perspective Plan (2010-2021), Seventh Five Year Plan (2016-2020) and a number of published articles and unpublished research reports related to climate change.

2 Brief description of the project

2.1 Background of the project

2.1.1 Climate variability in Bangladesh and Agricultural Drought

Bangladesh possesses a warm and humid climate, which is heavily influenced by pre-monsoon, monsoon and post-monsoon circulations. The average annual surface temperature is about 26˚C. However, there exists very strong seasonal and inter-annual temperature variability, ranging 15 to 34˚C, In the month of April, average temperature sometimes shoots to 38~40˚C, whereas in winter, it falls to as low as 6~7˚C. The beginning of summer (i.e, March-April) exhibits the highest daily temperature range (DTR) in comparison with other seasons. Figure-1 presents geographic distribution of average annual temperature over Bangladesh.

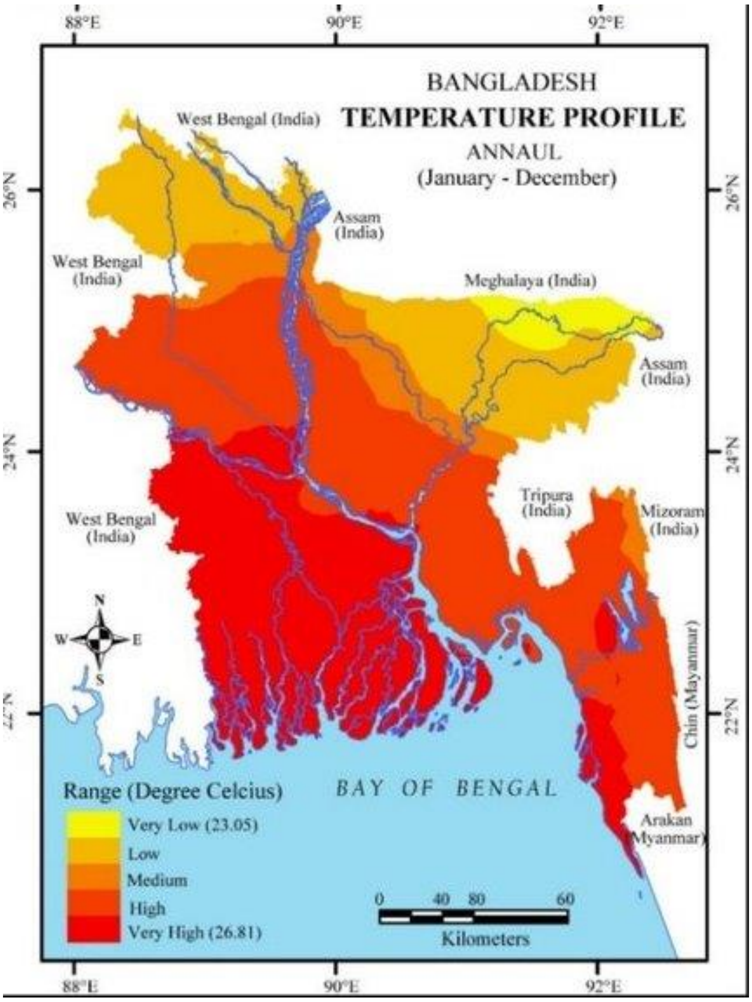


Figure 1: Average annual temperature distribution over Bangladesh

Although the south-western region is found to experience the hottest climatic condition on an annual scale, the hottest temperature isohytes propagate northward during the hot summer months (March through to September) and the north-west region (NWR) of the country also faces very high temperatures. Figure-2 presents average summer temperature distribution over Bangladesh, justifying the above findings.

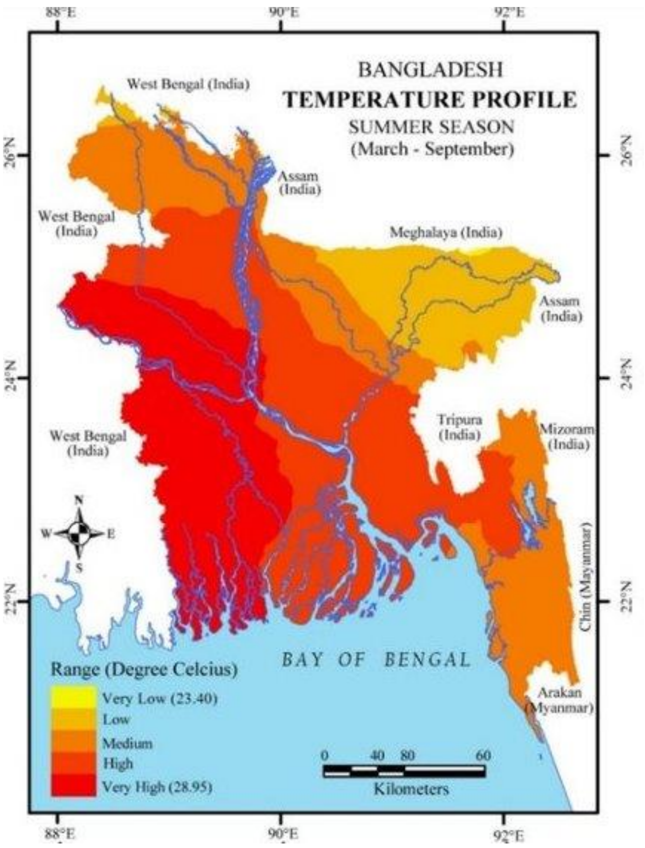
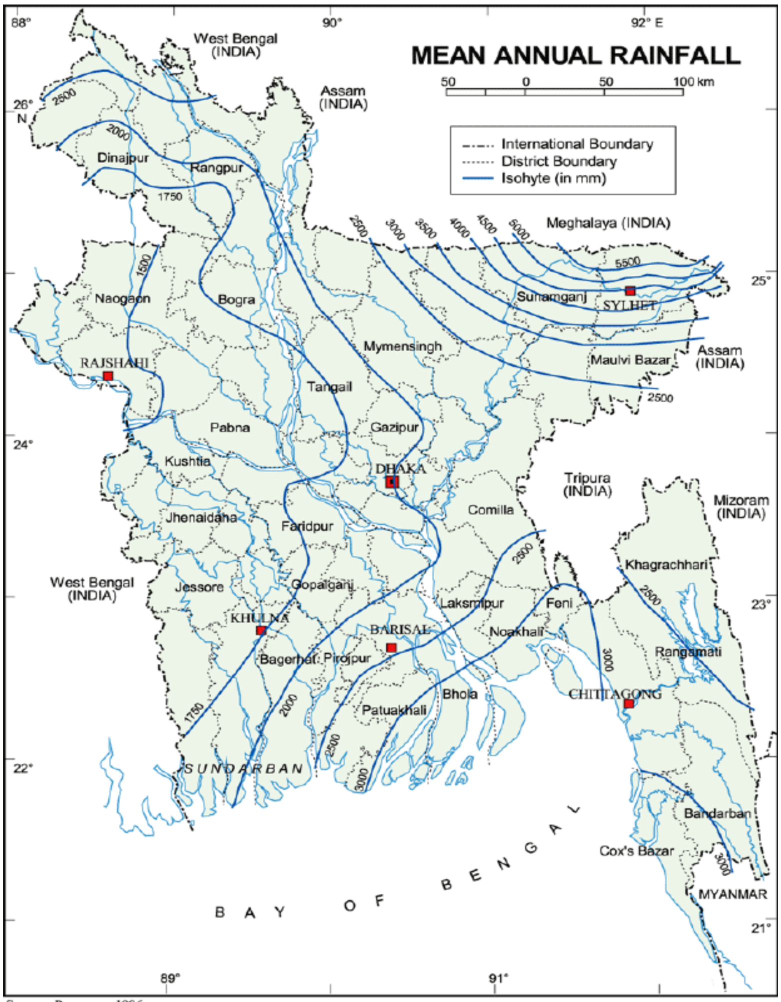


Figure 2: Average summer temperature distribution over Bangladesh

Climatologically, the country may be divided into two broad regions: the sub-tropical climate is found in central and northern sub-regions, while tropical conditions prevail in the southern sub-regions.

Bangladesh is generally regarded as a wet country, which receives on an average about 2,200 millimeter (mm) rainfall per year. However, the spatial distribution of annual average rainfall is acute, where the north-eastern region receiving over 5,000 mm and the central western region receiving below 1,500mm rainfall per annum. Figure-3 gives a pictorial representation of annual average rainfall across different parts of the country. Clearly, the southern parts of the NWR (i.e, Rajshahi and Naogaon districts) experience the lowest annual rainfall in the country.



Source: *Brammer, 1996*

Figure 3: Average annual rainfall distribution over Bangladesh

In addition to the prevailing wide spatial distribution of annual total rainfall, there also exists a significantly high temporal distribution of total annual rainfall. As presented in Figure-4 below, there is hardly any appreciable rainfall during the winter season (spanning between November through to February), followed by slight increase in a pre-monsoon (i.e, March through to May) compared to heavy monsoon rainfall (during June through to September). Available literature suggest that about 80% of annual rainfall occurs during the monsoon months (coinciding with *Kharif*-II season in the agricultural calendar), while less than 3% rainfall is observed during the dry period (November-February).

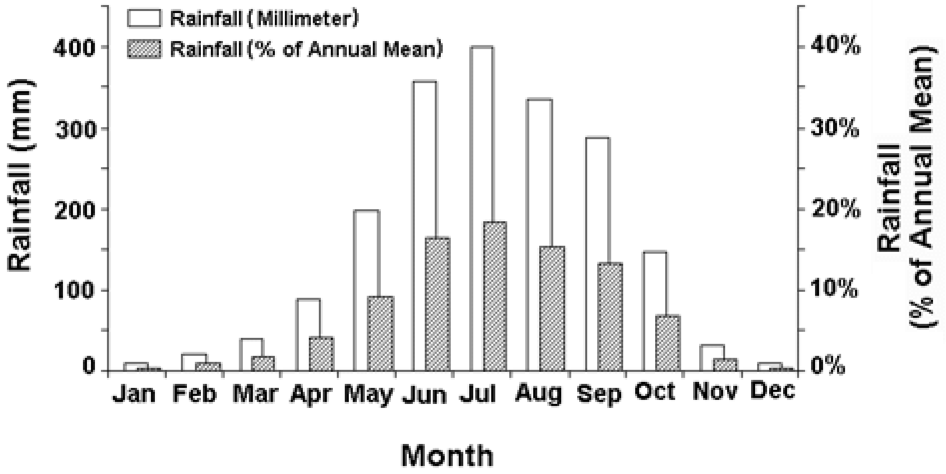


Figure 4: Month-wise distribution of long-term average rainfall in Bangladesh

The above-mentioned climatological findings lead to infer that Bangladesh generally faces two harsh realities: (a) the wet monsoon months offer an abundance of rainfall runoff over an almost flat terrain (being on the largest delta on earth with very little gradient) that causes floods to occur, and (b) the dry (winter) months provides for too little water due to acute seasonal distribution of rainfall. The latter reality becomes increasingly problematic in combination with the spatial distribution of rainfall, which gives unfavourable moisture conditions in the NWR (Ahmed et al., 2005).

Indeed, the available moisture disappears from the top soil profiles soon after monsoon months (i.e, October-November). Lack of rainfall in combination with rising annual temperature profile gives rise to decreasing SPI Index values (or increasing evapo-transpiration values), indicating agricultural drought. Under such conditions, the desiccation of moisture from the creeks and rivulets (i.e, known as *Khal*) expose the beds, arresting chances of natural recharge of groundwater aquifers. The non-availability of surface water used to discourage farmers to grow dry or pre-monsoon (i.e, local agricultural calendar identifies such cropping season as *Kharif-I*) crops, especially their staple paddy (which generally requires large quantities of water to grow).

With increasing population and subsequent demand for staple food, the farmers have started to exploit the dry season throughout the country, starting late 1970s. However, farmers had to defy drought conditions involving exploitation of groundwater resources. Throughout the country, farmers now grow *Boro* paddy, a photon-sensitive dry season staple crop, which performs well if drought is managed by groundwater irrigation. The changed reality has resulted in the cultivation of high yielding modern varieties of *Boro* (such as BRII-*Dhan* 28 and 29), which contributes to over 58% of all foodgrain cultivated in any given year and help maintain national food self-sufficiency.

The above-mentioned scene regarding cultivation of crops has given rise to a differentiated resource endowment for the NWR. Since the NWR experiences an unfavourable moisture condition with respect to that for the rest of the country (Figure-3 gives the spatial distribution rainfall isohytes), the (agricultural) drought condition (henceforth called drought) in the NWR is far more acute than that compared to the rest of the country. The North-western Barind region/districts of Bangladesh suffer the most from droughts (BBS, 2015). Figure-5 presents geographical distributions of drought intensity across the country. Clearly, the districts of

Rajshahi, Naogaon and Chapainawabganj (as depicted in Figure-3 above as well) faces the worst droughts in the country.

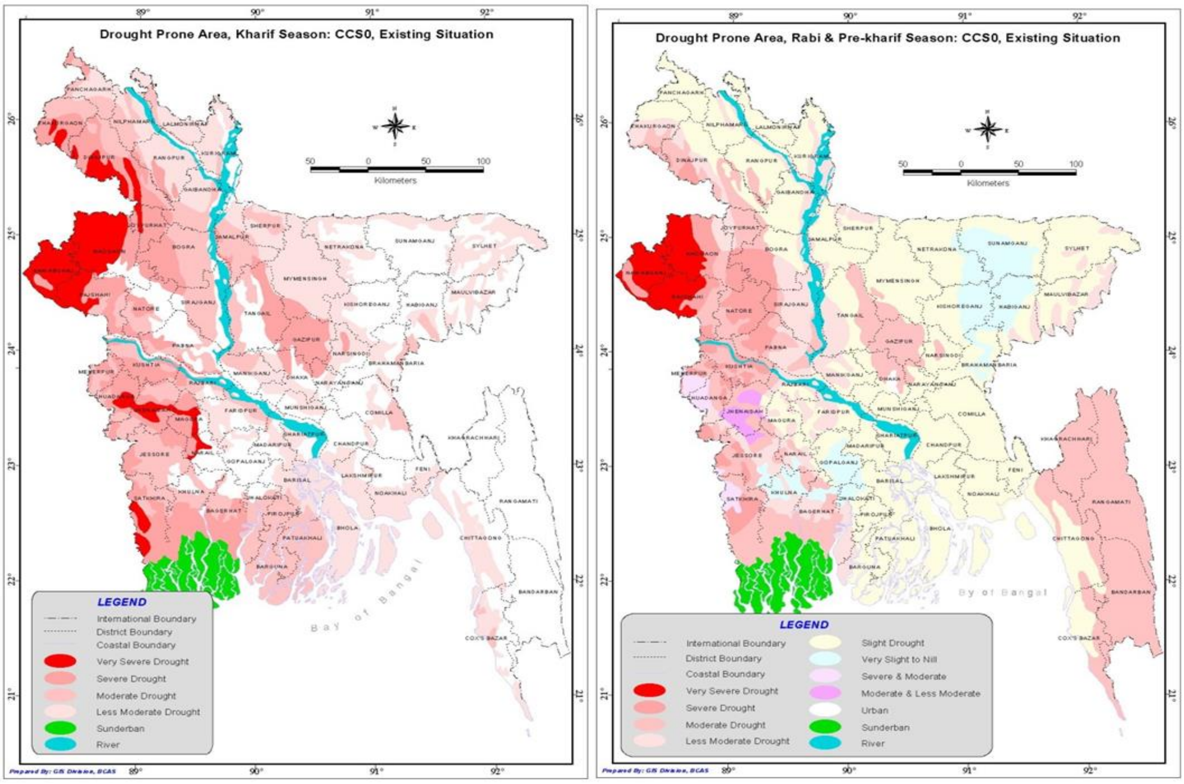


Figure 5: Geographic distribution of drought across Bangladesh under long-tern climate. (a) for monsoon (i.e, Kharif-II) and (b) for Winter (i.e, Rabi) and pre-monsoon (i.e, Kharif-I) seasons

As indicated above, farmers in the NWR have kept utilizing a miniscule amount of surface water as available, in combination with groundwater (GW) that are abstracted from irrigation wells. The long-term climatological analysis involving observed datasets (provided by the Bangladesh Meteorological Department, BMD) representing the NWR indicates that the average temperature over NWR annually and across seasons have been increasing, while the monsoon rainfall is slightly increasing and the winter and pre-monsoon seasonal rainfall is declining (results have been obtained by performing Mann-Kendal Tests and Sen's trend line analysis). Figure-6 presents a declining trend of total annual rainfall over the NWR, based on analysis of observed datasets (1985-2015). The increasing Rabi and Kharif-I temperatures along with declining total annual rainfall giving rise to increasingly challenging drought condition during the baseline years (1980-date).

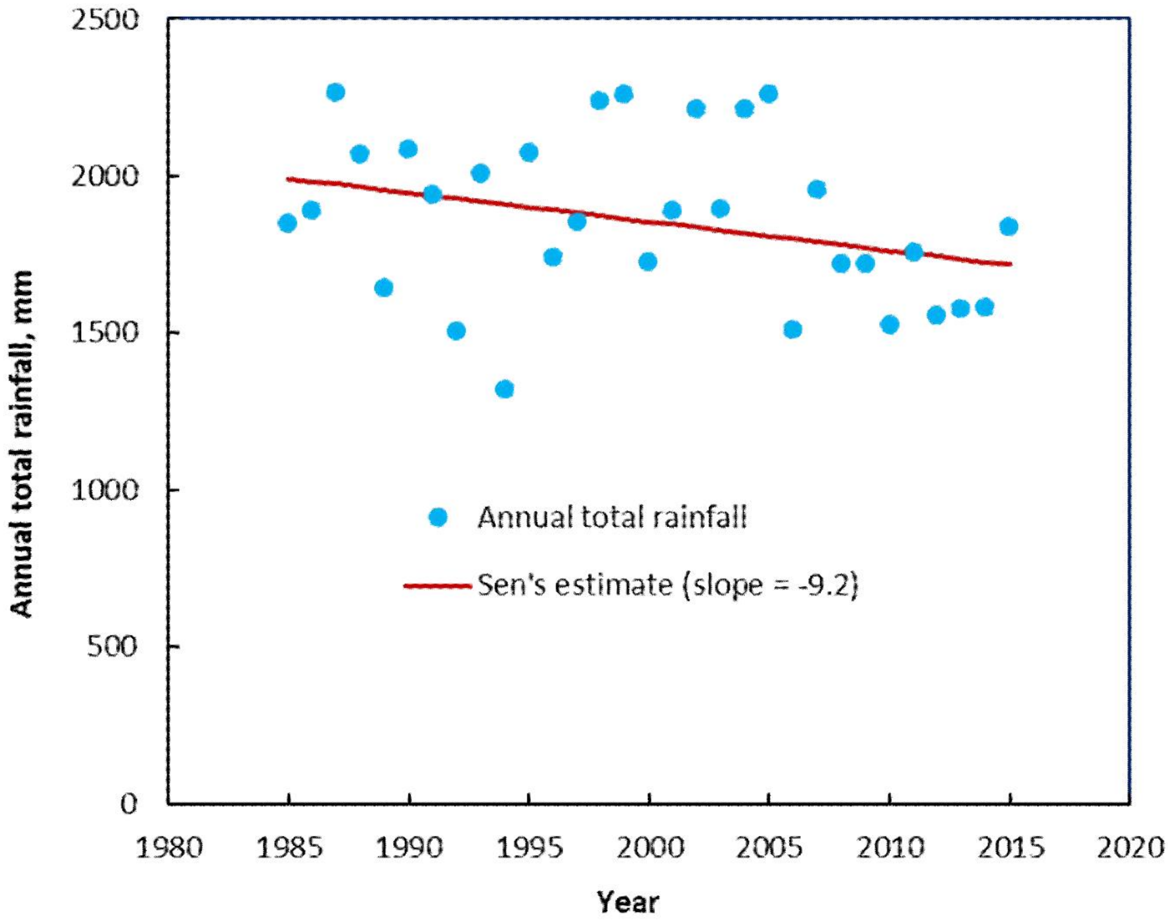


Figure 6: The declining annual total rainfall trend in the NWR, supported by Mann-Kendal Test

The Southern NWR houses the Barind Tract, which is a naturally uplifted area with thick claye layer (up to 12~15 meters thick) on the surface. Due to its soil characteristics, the water holding capacity is low and its allowance to percolate water in the sub-surface aquifers is rather low. Adham et al. (2010) showed that only 8.6% of available rainfall gets infiltrated into ground water aquifers. The appreciable natural recharge of GW tables generally occurs some 11 to 13 weeks following the monsoon rainfall runoff. The natural sedimentation process has choked many rivulets, thereby contributed significantly towards reducing recharge capacity of the natural creeks and rivulets. Historically, farmers themselves have excavated many ponds throughout the NWR so that these ponds can store some water in their neighbourhoods, and also it might contribute to the recharge of the GW aquifers. However, the poor farmers have little means to maintain such ponds/ community-ponds, which is why the environmental function of the ponds towards recharge could no longer be maintained.

The Government of Bangladesh has established a legally mandated body named the “Barind Multipurpose Development Authority (BMDA)” so that it may assist the inhabitant of Barind region towards their socio-economic development. BMDA realized that the lifeline for cropping of the most preferred varieties (namely BRII-*Dhan* 28 and BRRI-*Dhan* 29) is irrigation. Therefore, they offered deep tubewell based irrigation by abstracting GW from further below than the shallow tube wells (STW) that used to be engaged by the farmers. This was how the poor farmers in the greater Barind Tract were brought under the coverage of cheap irrigation sources within the command areas of the irrigation canals. The application of deep tubewells significantly reduced the dependence on costlier alternatives of irrigation such as the use of low lift pumps (LLP) and/or shallow tubewells (STW). This was how about 97% of the irrigated areas in the NWR including Barind Tract was brought under GW irrigation. The more powerful deep tube wells compared to LLP and STW helped overcome the growing drought problem, also intensified the lowering of the GW aquifers.

Since modern high yielding rice varieties require far too much of water in a single crop cycle (i.e, about 1,600 m^3 water per kilogram of paddy harvested[1]), with increasing dependence on dry season Boro cultivation, the abstraction of GW has reached beyond a tipping point in the NWR. Figure-7 depicts the gradual decline in GW table in Godagari, Rajshahi which has been observed through a trend analysis on hydrographs between 1995 and 2015. Available literature have indicated that, if the current cropping practices are continued and further intensified, the GW endowment might not be sufficient to offset moisture stress (Hussain et al., 2019; Hodgson et al., 2021). Figure-8 presents hotspots of declining groundwater tables in the Barind areas. The observed rate of decline in GW table is 0.7 to 0.8 meters per year.

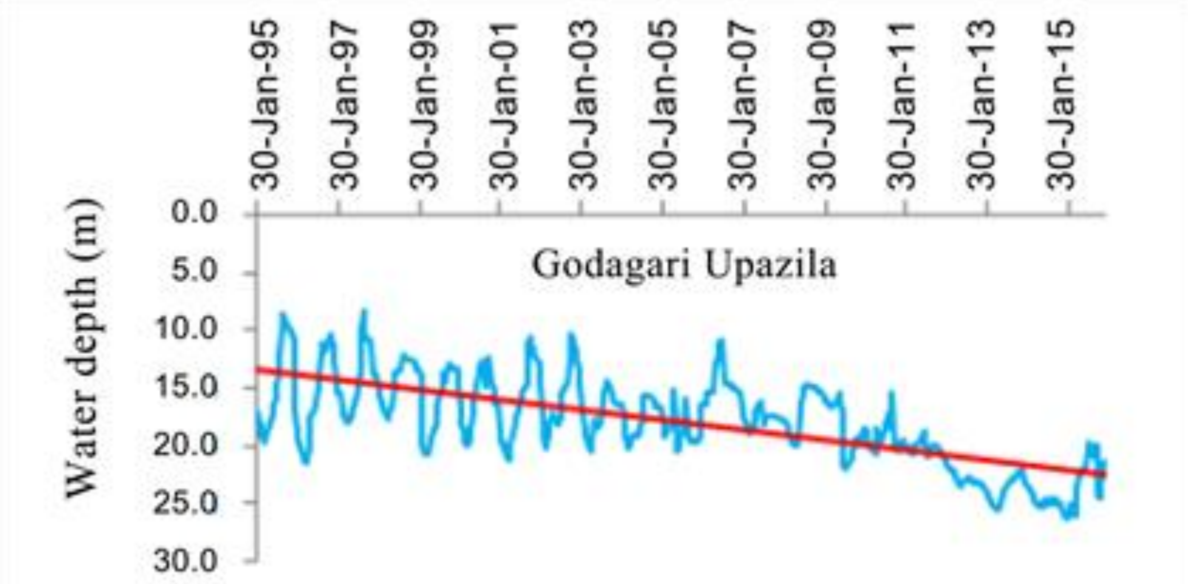


Figure 7: Declining hydrographs exhibiting a trend of ground water table in Godagari, Rajshahi

[1] Md Moniruzzaman, 2023. Personal Communication with the Principal Scientific Officer, Bangladesh Rice Research Institute (BRRI), Gazipur. The range of GW being applied is 1296 ~ 1821 liters/kg in different districts.

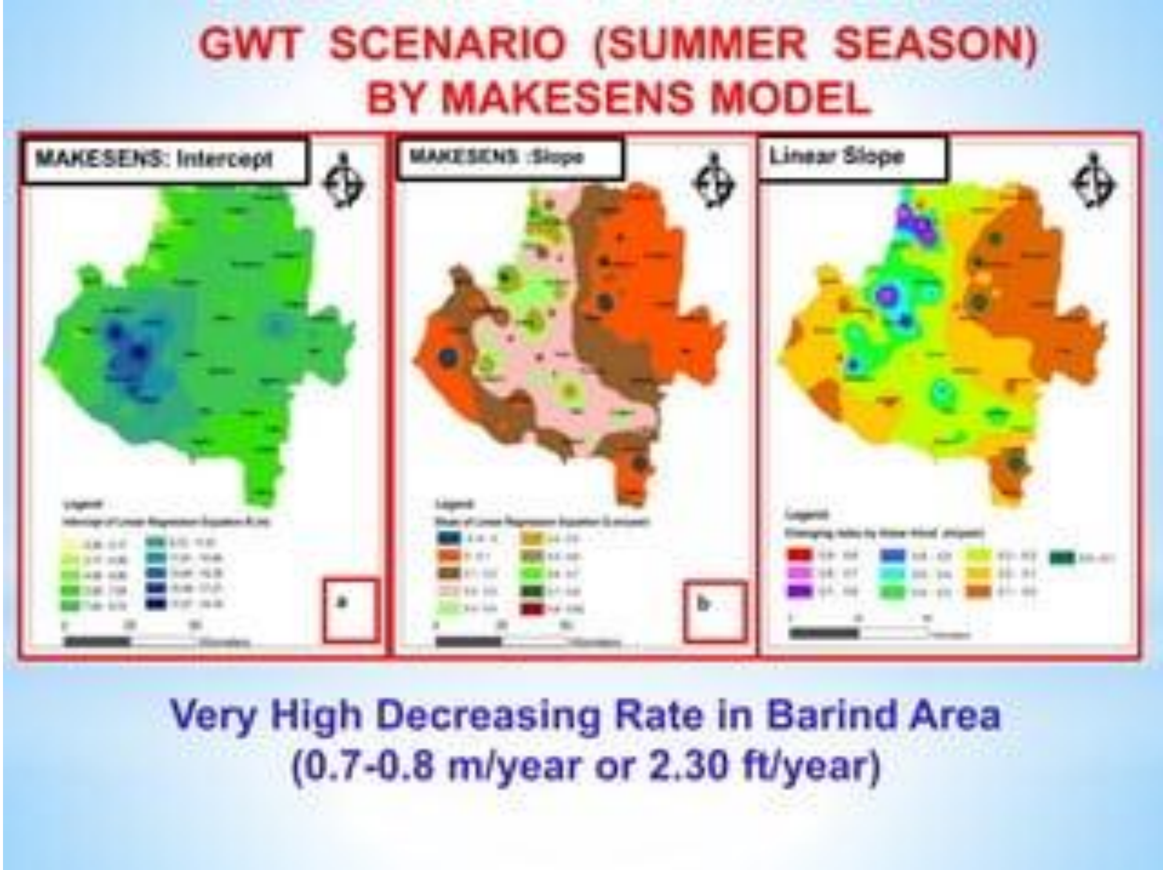


Figure 8: Hotspots of declining GW tables in the Barind areas (from Rahman et al., 2016)

The dryness or aridity in the NWR is not only an agricultural phenomenon, it has a strong social dimension too. The millions of villagers throughout the SWR depend on GW as their only potable source of drinking and cooking water, if not for other household activities such as washing and bathing. Such potable water from GW aquifer is generally abstracted by using hand tubewells. The shallow water tables found within 5 meters from the surface could easily be used throughout the year for the collection of potable water. However, with the advent of modern cultivation and subsequent lowering of GW aquifer, some tubewells appear non-functional during the peak dry season (Mid-February onwards), especially in hot spots in the NWR. Since the piezometric surface of GW aquifer in the SWR, used to be found generally below 8 meters from surface, declines up to 16 to 20 meters below surface, the tubewell heads that are established at shallow levels (such as 5 to 8 meters below surface) no longer find water within their range. As a consequence, those tubewells appear non-functional for several months, till the aquifers are naturally recharged.

Women are generally the water collectors for an average household in rural Bangladesh. Since there is a growing seasonal scarcity of potable water in hot spot areas, women in those hot spots are forced to drudgery under scorching hot summer conditions. Many women are found to go several kilometres on foot to fetch a pitcher full of water, which not only a labour-intensive unpleasant work, it also takes away valuable time for them to relax or engage in other important household chores.

The seasonal decline in water surface below ground and increasing drought condition leave little room for women (and even male members of an average household) to cultivate vegetables in their homesteads for household consumption. In rural Bangladesh where there is no such water scarcity, women generally grow vegetables on their own, with little support from their respective male counterparts, in a bid to meet the need for vitamin-enriched vegetables. However, this is not the picture in the NWR. The lack of water appears to be the limiting factor for homestead-based gardening and horticulture, while both could be the sources of valuable nutrients for family members.

2.1.2 Climate Change Induced Drought Problem Statement

Climate change is changing the nature of droughts in Barind region. The number of consecutive dry days and temperature has increased steadily over the past 30 years (MoEF, 2009). Thus, drought episodes have become more frequent and more severe due to climate change, a trend that has a high probability of worsening in the next decades.

Drought causes several challenges for vulnerable communities of the Barind region. The terrain lends itself to rapid run-off. Hence, almost all natural surface water sources evaporate during drought. So, the region remains dry for an extended number of days, leaving very little water for drinking, sanitation, or agriculture.

The human cost is measured in a greater incidence of disease, especially among children and lack of nutrition due to crop failure, increased poverty, and reduced development potential.

The current government policy response is maladaptive, relying on supplying deep tube-wells with underground irrigation networks that abstract water from the underlying aquifer that leads to over-extraction of ground water (GW). This enhances lowering of the ground water table (GWT), which is expected to eventually lead to functional extinction of the aquifer itself. In recent years, government has realised the rapid depletion of ground water and is trying to develop surface water irrigation by developing large irrigation infrastructure to divert river water or to excavate canals/ponds.

Traditional agriculture depends on a large quantity of available water extracted through the practice of flood irrigation, which competes with all remaining surface water uses and further exacerbates the problem of water over-abstraction from ground water.

The ability for communities to resolve this climate crisis and address barriers is severely limited due to their lack of adaptive capacity in the form of: lack of knowledge of climate change and its impacts; limited adaptive response options, especially around sanitation and agriculture; lack of local governance to organise responses; lack of understanding and knowledge of water harvesting and storage techniques; and lack of organisational and financial ability to implement and maintain infrastructure, to name a few.

Also, community institutions are weak and have neither the ability nor incentive to scale at a pace necessary to ensure sustainability of the ground water, the only available water resource during droughts.

2.1.3 ECCCP-Drought Project – A Paradigm Shift to Sustainable Water Use

The analysis of climate change context in the feasibility report suggests that the monsoon period is gradually shifting and becoming shorter. At the same time, ground water depletion due to over-exploitation together with rainfall variability and temperature rise are worsening drought conditions. Hence, drought causes a decrease in agricultural output leading to loss of livelihoods and food insecurity. It also has direct health impacts since it reduces access to safe water and forces people to use unsafe water for domestic uses. Moreover, water infrastructures are not properly maintained, which reduces available water. Women must walk several miles to fetch water during the dry season.

Traditional agriculture depends on a large quantity of available water extracted through the practice of flood irrigation. The current government policy response is maladaptive, relying on large infrastructure projects (e.g., ground water irrigation infrastructure by BMDA) to install deep tube-wells that abstract ground water from underlying aquifer for irrigation and drinking. This leads to an over-extraction of groundwater and lowers the GWT. It is expected that this vicious cycle will in the end lead to the functional extinction of the aquifer.

The paradigm shift that the project will promote will be based on the promotion of an Integrated Water Management (IWRM) concept using the‘4-R’ approach to water management: Reuse, Recharge, Recycle and Reduce. More specifically, the paradigm shift will consist of the following main elements: i) shifting from unsustainable use of scarce water resources to sustainable management of groundwater and surface water resources, ii) building institutional capacities to address water scarcity problems at grassroots level and among regional government authorities and the central government, iii) substantially reducing water consumption needs for agricultural productions, and iv) promoting cropping patterns that are drought tolerant and consume less water.

This project seeks to increase the adaptive capacity of communities and community institutions that includes gender equality so that they are enabled to develop local solutions to climate issues including good water management, infrastructure maintenance and planning for household and drinking use. It will seek to reduce the overall water footprint by promoting the use of low water intensity crops for dry season production, which will reduce irrigation needs by up to 70% in the winter season (30% for year-round irrigation)while also protecting livelihoods and meeting nutritional needs.

It will also increase access to water for drinking and for agriculture by providing greater proximity of clean drinking water access through provision of innovative water technologies, i.e., implementation of Managed Aquifer Recharge (MAR) model, thereby reducing the burden on women and reducing disease occurrence among children. It will also rehabilitate and improve the design of dysfunctional ponds and canals, providing a source of surface water in the dry season for irrigation purposes. This will meet a significant proportion of irrigation needs under the new paradigm.

In order to balance the water budget to reserve ground water for generations, this project will implement Managed Aquifer Recharge (rainwater directed through tubes to aquifer), which will be designed in a way that it replenishes ground water reserves with 100%or more of the volume abstracted.

This project seeks to design and implement a scaling methodology for sustainable water management from the business-as-usual paradigm before Ground Water (GW) resources are severely depleted. At an institutional scale, the project will strategically involve the Barind Multipurpose Development Authority (BMDA) from the design phase that will allow BMDA to build capacity and mainstream sustainable water management after the project end. At the community scale, communities with greater knowledge will increase their adaptive capacity and continue to practice low water intensity farming. The Government has adopted MAR strategy where an MAR centre is proposed. The project will support the government to establish the MAR centre. In addition, NGOs (MFIs) will be enabled to offer financial services for climate adaptive technologies to communities, thereby adapting the relationship of community level institutions to the current development situation.

The proposed interventions are low-cost solutions that are in line with relevant national policies. The capacity building activities that the project will promote will enable NGOs and government authorities to scale up and replicate the typologies of project interventions that have been promoted by the project. More precisely, the establishment of a climate change unit within BMDA will facilitate the replication of the innovations promoted by the project in the whole region. In the same way, the establishment of an MAR centre within the Ministry of Water Resources will enable the government to gain specialised skills to increase the number of MARs in the country, thus compensating groundwater over-exploitation. Both BMDA and the Ministry of Water resources play a key role in water management issues in the country and are expected to scale up the proposed interventions in the future with support from government budget and other development partners.

2.2 Selection of project area

The project area was selected based on the relative intensity of climate hazard and severity of impact within The Barind Tract (see Figure 9).

The project areas were selected based on the intensity of drought and vulnerability of exposed populations. An analysis of the spatial distribution of severe drought using the Standard Precipitation Index (SPI) shows that the highest frequency of extreme droughts is in the Northwestern part of the country, especially in the high Barind Tract, which includes the districts of Naogaon, Chapainawabganj and Rajshahi (more information is in section B1; further details are provided in Annex-2, the pre-feasibility study report). Although drought incidence is not confined to North-western Bangladesh, the frequency of drought is higher in the districts of the Barind Tract[2]. Records also show that there were only five severe droughts from 1791 to 1900 and that the frequency increased significantly after 1951**Error! Bookmark not defined.**. Since 1981, four severe droughts have affected the agriculture sector. They were mostly concentrated in North-western Bangladesh**Error! Bookmark not defined.**.

The Bangladesh Agricultural Research Council (BARC) identified seasonal drought-prone areas and ranked by *Upazila*[3]on the basis of the Bangladesh Agricultural Research Council (BARC) drought map[4]. The third national communication of Bangladesh to the United Nations Framework Convention on Climate Change (UNFCCC) has identified ten drought hotspots, which are located in six districts of the NWR. Out of ten hotspots, four are in Naogaon (Sapahar, Patnitala, Porsha and Niamatpur), two in Chapainawabganj (Nachole and Gomastapur) and one in Rajshahi district (Godagari) representing the Barind area. However, when one superimposes rainfall runoff and infiltration characteristics of Barind area and hydrological limitations (details in Annex-2) and also socio-economic aspects of affected communities, several other sub-districts are found to extremely vulnerable to droughts. The additional sub-districts (i.e, Upazilas) include Dhamoirhat, Badalgacchi, Mohadevpur, Manda and Naogaon Sadar of Naogaon district; Shibganj Upazila under Chapainawabganj and Godagari upazila under Rajshahi districts, which are also severely affected by drought (MoEF,

[2]FAO, (2006) Livelihood adaptation to climate variability and change in drought-prone areas of Bangladesh, Implemented under the project 'Improved Adaptive Capacity to Climate Change for Sustainable Livelihoods in the Agriculture Sector – DP9/1-BGD/01/004/01/99', Food and Agriculture Organization, VialedelleTerme di Caracalla, 00153 Rome, Italy.

[3]Upazila, formerly called thana, is an administrative region in Bangladesh. They function as sub-units of districts.

[4] BARC (2001). Application of agro-ecological zones database in drought management and water availability assessment report, prepared by environment and GIS support project of water sector planning, Ministry of Water Resources, Government of Bangladesh, Dhaka

2009)[5]. Figure 9 presents the map of Barind areas including the three target districts and their sub-districts.

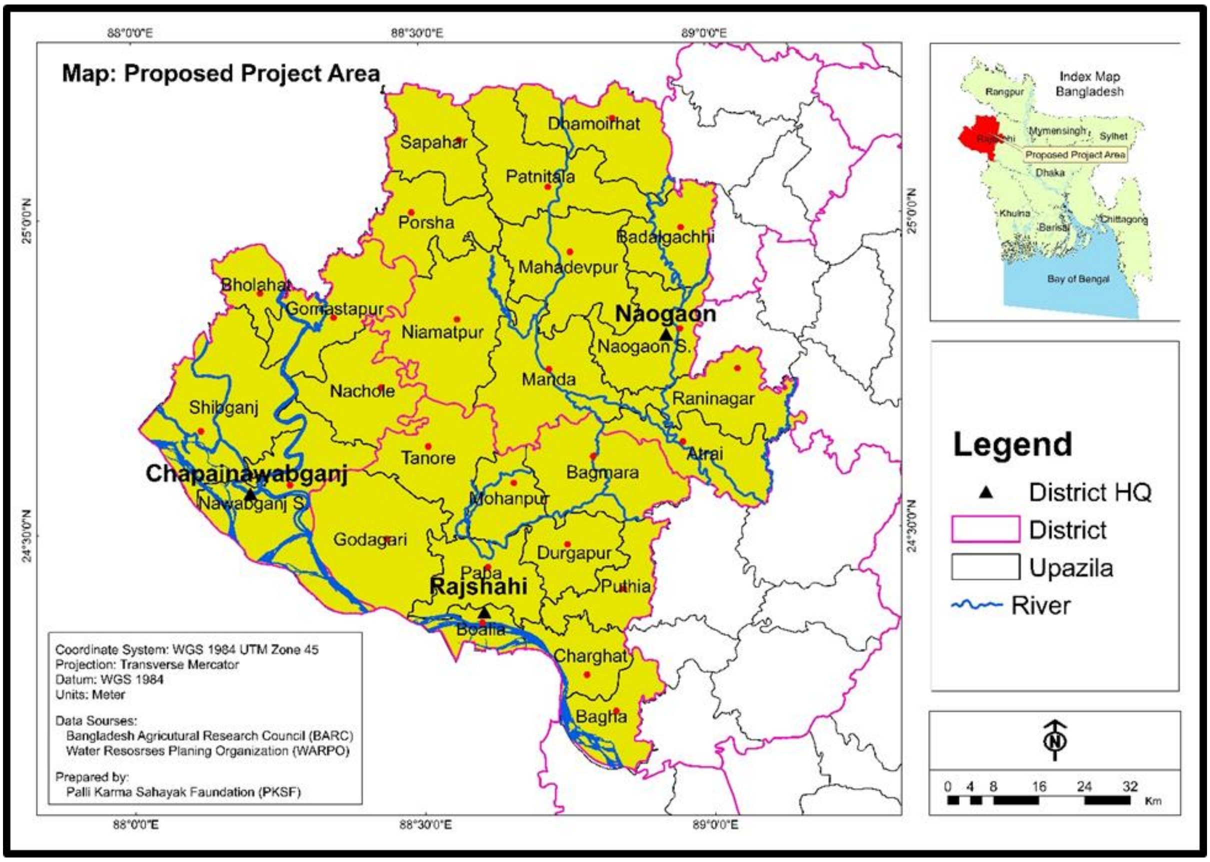


Figure 9: Proposed Project Area

[5]MoEF (2009). National Adaptation Programme of Action (NAPA), 2009, Ministry of Environment, and Forest (MOEF), Government of Bangladesh.

3 Climate Change Context and baseline

3.1 Climate and climate trends

3.1.1 Climate change: Bangladesh context

Bangladesh is sub-tropical but displays a tropical monsoon climate characterised by heavy summer rainfall and high summer temperature (MoEFCC, 2018). The reason for these climatic conditions is Bangladesh's geographic location; the Himalayan Mountain range acts as a barrier to moisture-laden monsoon winds in the summer season which cause intense rainfall and helps protect the country from extreme cold wind blowing towards it from the North (MoEFCC, 2018). Seasonal variation of rainfall and temperature is remarkable in the country. This section provides some analysis of temperature and rainfall to understand the trend of climate in the country. The Third National Communication (TNC) has analysed temperature and rainfall based on eight hydrological regions as divided in Master Planning Organisation (MPO) in 1986 (Figure 10).

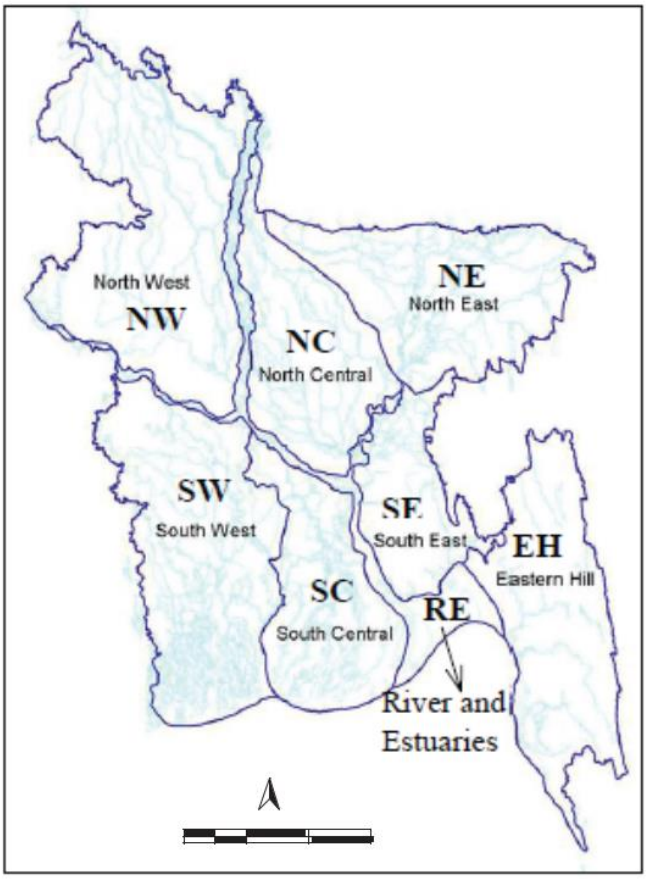


Figure 10: Hydrological Regions of Bangladesh (MPO, 1986)

<u>Temperature</u>

Bangladesh has a considerable observational climatological daily dataset involving several parameters such as maximum daily temperature (T_{max}), minimum daily temperature (T_{min}), daily rainfall, daily humidity, etc. There are over 30 weather stations which regularly collect daily data manually. Such data are archived, collated (digitally) and managed on behalf of the state by the Bangladesh Meteorological Department (BMD). Seven of all the stations feed the global climatological data repository maintained by the World Meteorological Organization (WMO). Despite the fact that there are lapses regarding continuity of station-specific datasets due to war of independence and other unavoidable issues in the past, the station-based climatological datasets are adequate to understand long-term baseline climatology of the country. Twelve (12) of these data stations provide near-complete observational datasets[6] starting 1960.

A time series of 1960-2015 was picked for understanding the baseline climatology of the country. Bangladesh is generally experiencing rising temperatures. The mean annual temperature rose by 0.0056°C/year from 1961 to 2014 (Figure 11). The mean annual maximum, average, and minimum temperature have also increased by 0.02^{0}C/year, 0.016^{0}C/year and 0.012^{0}C/year, respectively (MoEF, 2013).

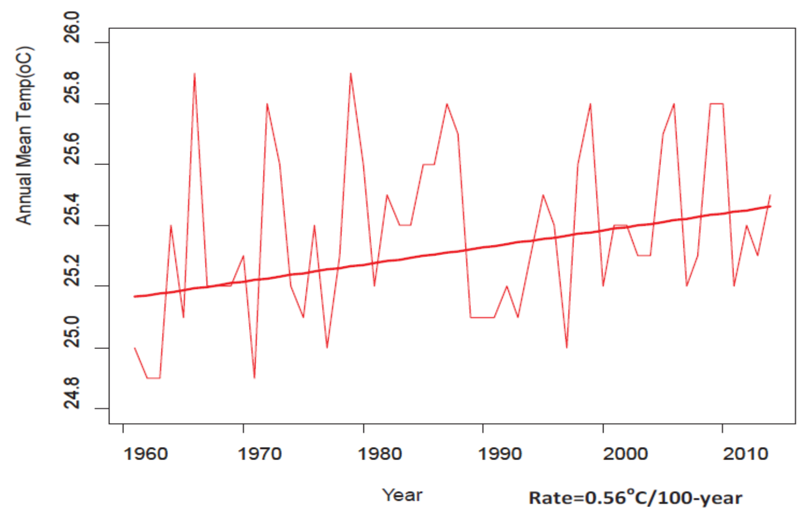


Figure 11: Trend in Annual Temperature in Bangladesh (1961-2014). The trend line demonstrates Sen's slope

Nishat and Mukherjee (2013) analysed seasonal temperature trends for Bangladesh. Their analysis shows that over the past few decades, most of Bangladesh experienced warmer winters with a prominent increase in the minimum temperature (Nishat and Mukherjee, 2013). Hotter summers were also experienced during the pre-monsoon and monsoon months with a prominent rise in the maximum and minimum temperatures. Over the last 40 years, an increase in the minimum temperature by 0.45°C and 0.52°C was observed during the winter (December, January, and February) and monsoon (June, July and August) season, respectively. Maximum temperatures were also observed to have increased during the pre-monsoon (MAM) and post-monsoon (JJA) months by 0.87°C and 0.42°C, respectively. A rise in the minimum temperature during the winter season (DJF) was observed in 25 out of 34 climate observatories of the BMD. A rise in the maximum temperature during the hot summer months of JJA was observed in almost all the stations (Nishat and Mukherjee, 2013).

<u>Rainfall</u>

Several homogeneity tests involving the recorded observational rainfall data are performed to reveal that rainfall data are generally homogenous (Shahid, 2010). Mann-Kendall tests are performed to detect trends involving rainfall datasets. Sen’s slope analysis gives a robust

[6] Missing data corresponds to less than 2% for these stations.

estimation of the trend thus observed. As indicated in previous sections, the NWR receives the least amount of rainfall compared to other parts of the country. Figure-12 presents rainfall distribution in the NWR of the country. Clearly, the Barind region receives the least rainfall.

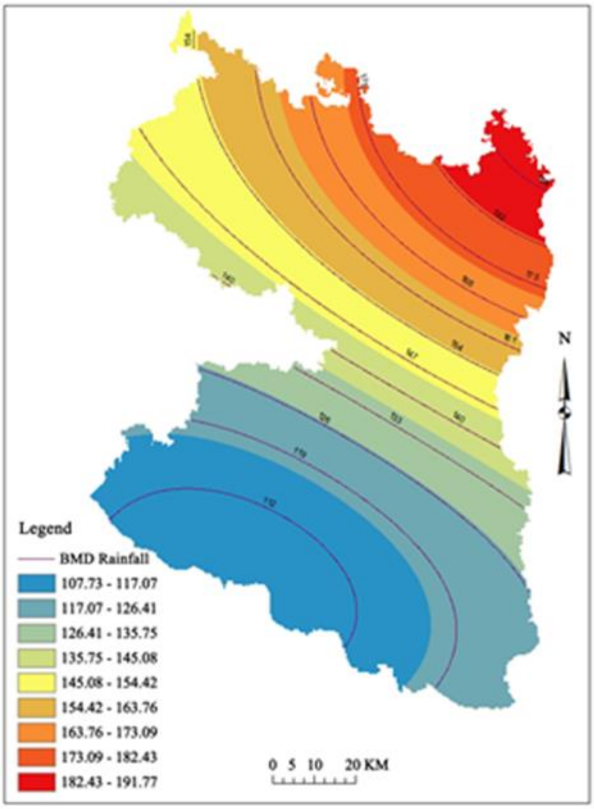


Figure 12: Rainfall distribution map for the NWR exhibiting the least amount of rainfall in Barind

The average annual rainfall in Bangladesh from 1961 to 2014 was 2,488 mm and the range was from 1,917 to 2,901 mm. The analysis of annual rainfall by Sen's slope method is found to be increasing at a rate of +5.525 mm per year in Bangladesh. About 80% of the annual rainfall occurs during the monsoon months (June-September). The monsoon is both hot and humid and the country experiences torrential rainfall throughout this season. Post-monsoon is a very short season with little or no rainfall and low night-time minimum temperatures. It is found that, both post-monsoon (October-November) and winter (December-January-February) rainfall trends exhibit no appreciable change in rainfall over the country.

The maximum mean seasonal rainfall increase observed during the pre-monsoon (MAM) and monsoon (JJA) is around 100 mm. However, the Mann-Kendall test reveals that such trends for the pre-monsoon rainfall is not significant. Although the winter season (DJF) experiences the least rainfall, an incremental positive trend is observed in 27 out of 32 rainfall stations of the Bangladesh Meteorological Department (BMD). There exists high spatial variability in changes in annual mean and seasonal rainfall. The coastal zone has been experiencing higher increased rainfall than the Barind region. Various models including Global Circulation Models (GCMs) show that these changes will be continuing in the future with greater uncertainty (MoEF, 2009).

However, in contrast to increasing precipitation, Islam et al. (2014) showed an increasing trend in consecutive dry days (CDD), suggesting higher annual precipitation concentrated into a shorter period of time than the baseline period (1980), leaving long dry spells between days of rain.

3.1.2 Climate change in the project districts

The above analysis is repeated for the specific region of interest: the NWR of the country. A more recent sub-set of data are employed for the analysis of trends for the NWR. The figure below (Figure-13) shows an upward trend of maximum mean temperature in the 1980-2017 period in the North and North-west region of Bangladesh. The upwards rise in average annual temperature is matched generally by various seasonal temperature trends for the region. The winter seasonal rise outweighs the same for the other seasons, indicating a much sharper increasing trends for the winter temperature in the NWR of the country. The 38 years of data reveals a sharp rise in average annual temperature for the NWR. The rate of increase in average annual temperature (the slope being +0.014) is much higher than that for the entire country. This indicates that the signal of climate change is much pronounced in the NWR than elsewhere in the country.

The figure 13(a) also shows a decreasing trend for rainfall in the same period. More precisely, mean annual temperature has significantly increased by 0.014 °C/year over this period while rainfall has decreased significantly at 0.87 mm/year (Islam et. al., 2021). The combination of decreasing rainfall and an increase in temperature has a significant effect on occurrence of droughts in the project areas.

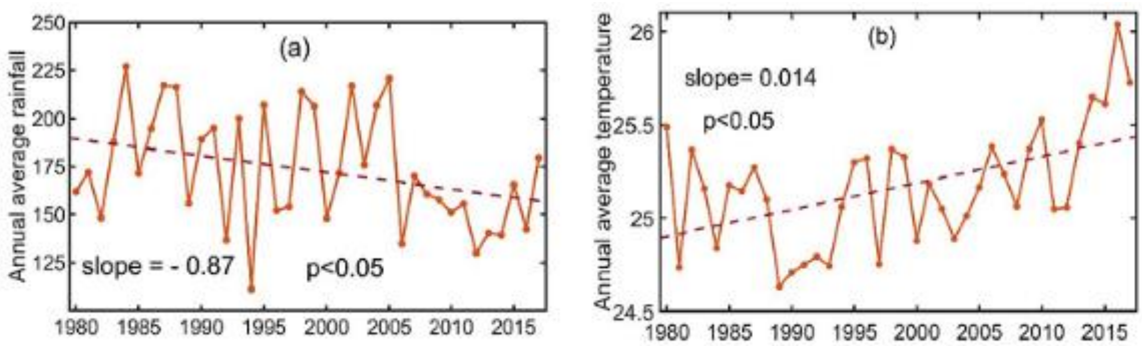


Figure 13: Rainfall and Temperature in North and Northwest Region of Bangladesh

Exploratory analysis of annual rainfall data has revealed that the Barind area (which includes Barind Tract and Floodplain areas of Rajshahi, Chapainawabganj and Naogaon districts) receives almost 39% less rainfall than the national average of Bangladesh. About 93% of annual rainfall occurs during the months of May-October with a high value of coefficient of rainfall variability (25.9%). In general, results of Mann-Kendall (*MK*) Trend Test for annual, seasonal and monthly rainfalls for the period from 1971-2015 show declining trends. Annual, winter, summer and rainy season rainfalls of the study area are decreasing at rates of -2.76 mm/year, -0.28 mm/year, -0.18 and -2.13 mm/year respectively. About 67% of rainy season rainfall time series shows decreasing trends and monthly rainfall trend analysis also indicate that rainfall during the peak monsoon months (July-September) shows declining trends.

Calculated seasonality index ($\overline{\boldsymbol{SI}}$) value (0.87) indicates marked seasonality of rainfall with a longer dry season and this finding is consistent with exploratory analysis of monthly rainfall patterns. Furthermore, the higher precipitation concentration index (***PCI***) values vary from 18.26 to 20.42, with an average of 19.84 indicating annual total precipitation occurs in few very rainy days and have the potential to cause frequent dry spells and resulting drought situations put considerable pressure on water resources in the area. Water balance study also indicates that deficit of rainfall starts in October-November that continues till May. The area suffers from high moisture stress for seven to eight months and irrigation is necessary for this long period. Trend analysis of potential evaporation transpiration (***P*ET**) reveals significant increasing trends that mean the difference between rainfall and ***P*ET** will be increased in the future and that will be the cause for more annual deficit in water.

For the development of the pre-feasibility, the project preparation team analysed rainfall data of the Rajshahi meteorological station covering the 1990-2014 period. Figure-14 presents rainfall trend found in Godagari station, Rajshahi district, clearly with a declining slope in recent decade. On average, 56% of annual rainfalls occurred within three months (July-August-September) and 84% occurred within six months (May to October). Since there is hardly any rainfall in winter months such as January, attempt was made to reveal trends of ground water depth below surface for the Godagari Upazilla of Rajshahi district (as a response to declining rainfall). Figure-15 presents the declining slope of GWT for Godagari. The higher occurrence of droughts in the North-western part of the country is due to the high annual variability of rainfall in the region. For instance, the rainfall recorded in the North-western part of the area in 1981 was 1,738 mm while in 1992 it was 798 mm (Dina et.al. 2020).

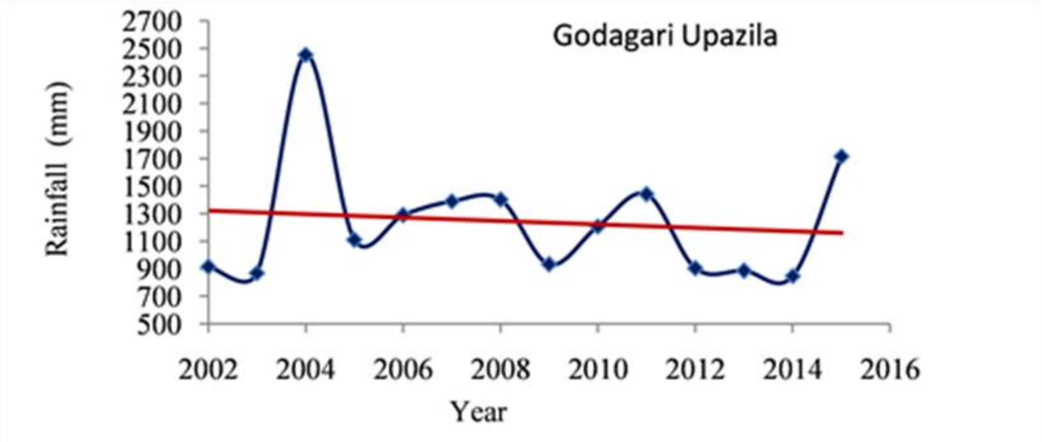


Figure 14: The declining trend of annual rainfall in Godagari, Rajshahi

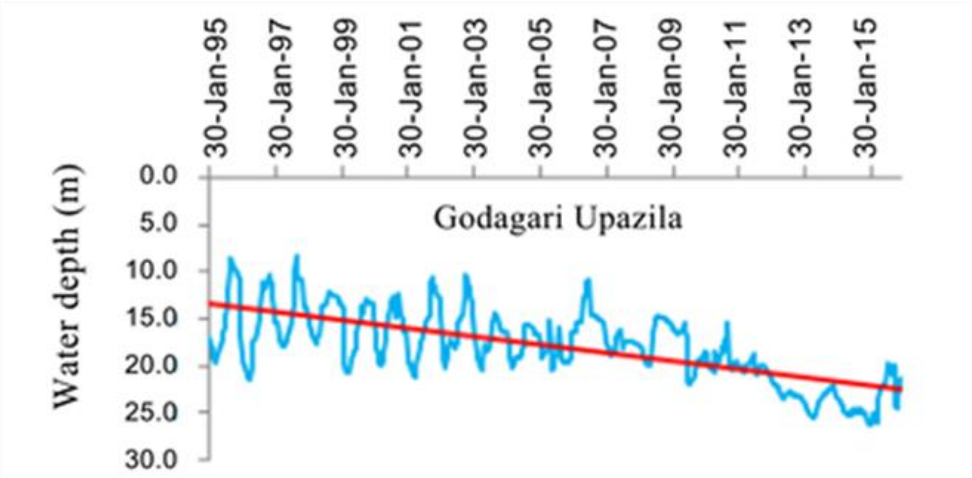


Figure 15: The declining trend of ground water table in wells in Godagari, Rajshahi

3.2 Climate related hazards and drought

Bangladesh is known internationally for its coastal zone related climate induced hazards. In the NWR or in the Barind area, there is no coastal zone and climate change-induced coastal hazards such as cyclonic storm surge, high wind speeds, and sea level rise induced salinity ingress are absent. However, the baseline climate change over the past three to four decades has shown early signs of adverse impacts in the forms of a rise in consecutive dry days (may lead to meteorological drought if there is no rainfall in consecutive 20 days), increasing heat stress due to rise in summer time temperature and an increase in monsoon rainfall leading to a drainage congestion and flood.

The Pleistocene uplifted physiographic unit called Barind Tract is bounded by the Karotoa river to the east, the Mahananda river to the west, and the northern bank of the Ganges river to the South. There are other three rivers criss-crossing the area: the Little Jamuna, the Atrai and the Lower Punarbhaba rivers, which occupy fault troughs. During the peak flood period in July and August, these rivers flow at their respective highest water levels through the Barind area. However, 88% of the landmass belonging to high to medium high lands, floodplains occupy only about 12% of Barind areas. Therefore, climate change induced flooding is not a major hazard in the project area.

Heat waves and heat stress are relatively new phenomena that are causing various hazards including crop loss, human health issues including sudden discomfort, even deaths. The maximum daily temperature rising above 40̊C for at least two to five days is defined as heat waves. Exposure to extreme heat reduces working capability, especially for people involved in outdoor activities such as farming and pulling rickshaws. It is claimed that the NWR of the country is particularly vulnerable to heatwaves. The BMD reports a significant increase in both maximum and minimum temperatures between 1990 and 2010 compared to a period of 63 years from 1948 to 2010 across the country. It is claimed that these heatwave events are affecting the health and livelihoods of the people. The International Labour Organization (ILO) reported that Bangladesh might lose 4.84% of total working hours due to heat stress resulting from surface warming by 2030 (ILO, 2019). Much of such adverse impacts is likely to be observed in the NWR of the country.

The project area is frequently subject to agricultural drought, as explained in the earlier sections. Since climate change will cause an increase in surface temperature during both the winter and the pre-monsoon seasons, it will have tendency to cause greater volumes of evaporation from the surface. However, the moisture loss from the root zones will be further aggravated due to decline in climate change induced rainfall, during both the winter and the pre-monsoon seasons. The combination of increasing temperature and declining seasonal rainfall under climate change will tend to increase evapo-transpiration losses that forces agricultural drought to occur. Figure-16 presents severely affected drought prone areas under baseline climate change scenario (CCS0).

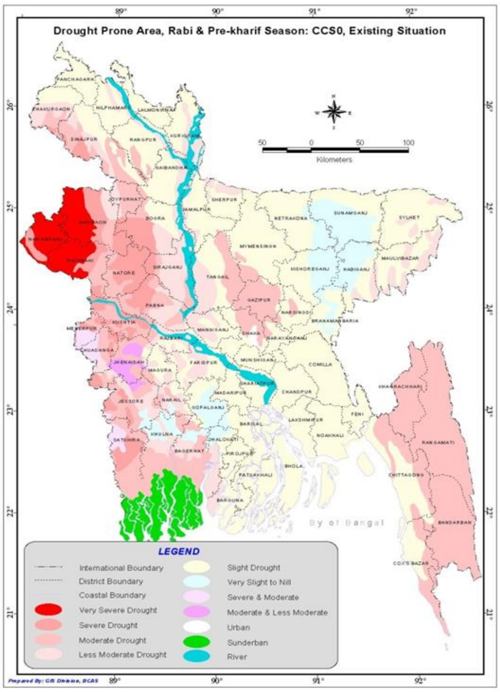


Figure 16: Geographical distribution of drought affected areas during pre-monsoon period

The United Nation Food and Agricultural Organization (FAO) has carried out people's perception on drought based on stages of crop life-cycle for defining drought in terms of dry spells (FAO, 2006). The study stated that on average, a dry spell of five to seven days is considered mild drought at seedling and flowering stages, but in the vegetative stage, it is seven to eight days. At flowering stage, the community considers a rainless period of more than 12 days to be a severe drought that could reduce crop yield by up to 40 percent. This analysis needs to be compared with agro-meteorological analysis using long-term rainfall data and projected climate change. Understanding of local thumb rules and local perceptions is necessary to identify a suitable adaptation practice that fits within the rules.

Usually, drought occurs in the pre-monsoon season when the potential evapotranspiration (PET) is higher than the available moisture due to uncertainty in rainfall, while in post-monsoon season it is due to prolonged dry periods without rain or less rain (Karim et al., 1990). The average occurrence of severe drought in the country is once in 2.5 years; nineteen severe droughts occurred in Bangladesh between 1960 and 1991, which affected as much as 47% of the country's area and 53% of the population throughout that time.

In the recent past, severe droughts occurred in the year 1965-1966, 1972-1973, 1978-1979 and 1982-1983. The extreme droughts in 1978-1979 affected the entire country, whereas in other years, drought was more or less localised – primarily in the NWR. In the 1990s, drought conditions in the north-western part of Bangladesh resulted in a crop loss of 3.5 million tons (GoB, 2012). During the 2010 monsoon, Bangladesh experienced the driest monsoon since 1994 with a seasonal rainfall total of about 19% less than the long-term average due to the relocation of monsoon further south than usual. Table 3 shows drought affected areas in Bangladesh.

Table 1: Drought affected areas by cropping season

Crop season	Area under various drought severity classes (in million ha)				
	Very severe	Severe	Moderate	Slight	Unaffected

Pre-kharif (summer)	0.403	1.15	4.76	4.09	2.09
Kharif (rainy)	0.344	0.74	3.17	2.90	0.68
Rabi (winter)	0.446	1.71	2.95	4.21	3.17

(Source: Ahmed and Roy, 2007)

3.2.1 Trends of Climate Change Induced Drought in the Project Districts

The occurrence of drought, as a major water deficiency related issue, is most profoundly experienced in the NWR of Bangladesh, especially in the districts of Naogaon, Rajshahi & Chapainawabganj (WARPO, 2001). The drought situation of the area becomes severe during April-May due to the cumulative effect of soils with low moisture holding capacity (<200 mm available moisture), increasing number of dry days (precipitation <0.5 PET), and occurrence of extreme summer temperature of more than 40°C. Figures 17-19 show geographical distribution of drought in different cropping seasons of the project area i.e. *Rabi* season (it is winter crop season that ranges from November to April), *Pre-kharif* season (March-June) and *Kharif* season (rainy season from June to October).

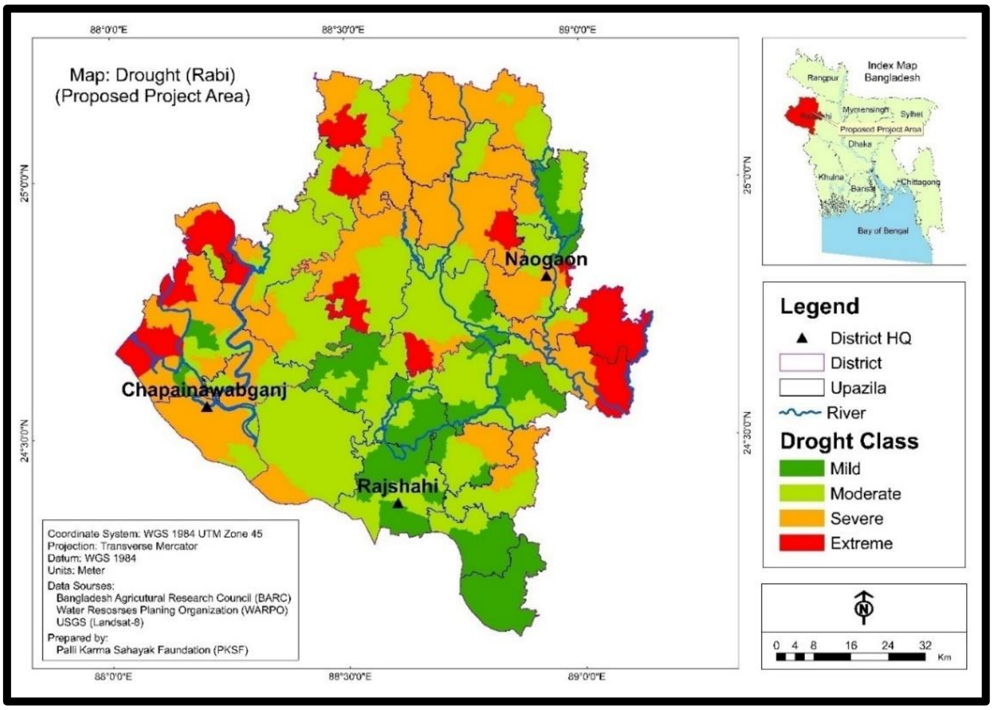


Figure 17: Spatial distribution of drought in the proposed project area (Rabi) season

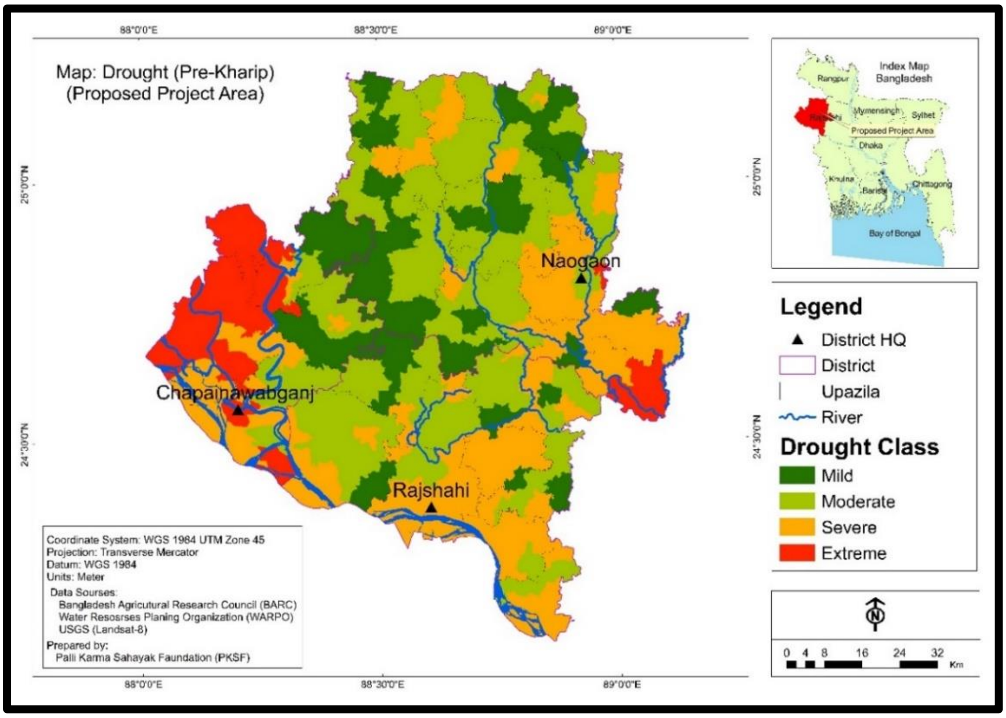


Figure 18: Spatial distribution of drought in the proposed project area (Pre-monsoon season)

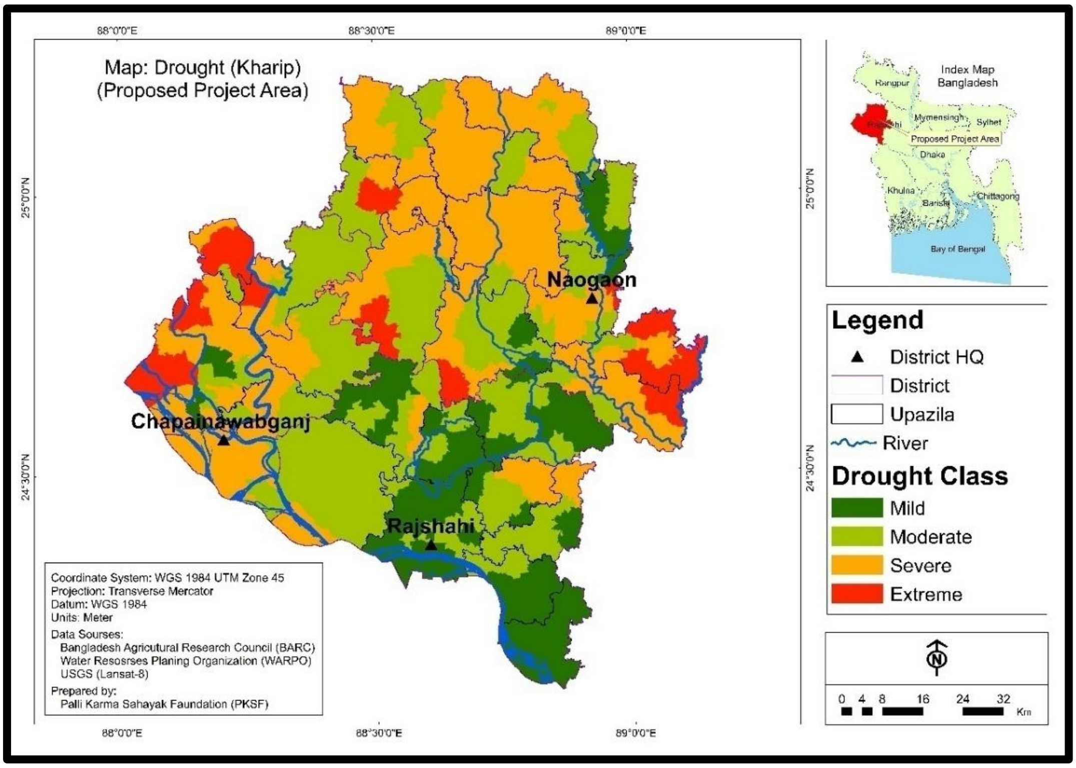


Figure 19: Spatial distribution of drought in the proposed project area (Kharif-II season)

During Rabi season, extreme drought[7] affects 10.32% and severe drought[8] affects 33.78% of the selected districts. On the other hand, 43% of the area is affected by moderate drought[9]. Thus 87% area of the districts is affected by moderate to extreme drought. Extension of extreme drought is higher during pre-*Kharif* season (summer), which is 39.21% followed by severe drought 30.78%, mild drought 19.32% and moderate drought only 10.69%. Again, more than 80% area of the selected districts gets affected by moderate to extreme drought which ultimate constrains food production and water resource development. Similarly, More than 82% are of the districts is affected by moderate to extreme drought during *Kharif* season. During this season, severe drought affects 37.28% and moderate drought affects 37.20% areas of the selected districts.

A study carried out by Bangladesh Centre for Advanced Studies (BCAS) in 2010 (unpublished research report) found that since the year 2000, drought has occurred each year during the months of *Chaitrya* (Mid-February to mid-March) to *Ashar* (mid-June to mid-July) and *Ashwin* (mid-September to mid-October). But after 2007, intensity and duration of drought and the impacts it has caused have increased particularly in 2008, 2009, and 2010. Historical analysis shows that although drought incidence is not confined to North-western Bangladesh alone, the frequency of drought is higher in the districts of the Barind Tract (FAO, 2006). Records also show that there were only five severe droughts from 1791 to 1900 and that the frequency increased significantly after 1951. Since 1981, four severe droughts have affected the agriculture sector, mostly concentrated in North-western Bangladesh (FAO, 2006).

The decadal frequency of drought is also found to be increasing. The total number of dry episodes was identified using the standard precipitation index (SPI)[10]. SPI values are highest in recent decades (2001-2010) and the numbers of mild and moderate drought events at SPI-3, SPI-6 and SPI-12[11] time-steps are increasingly prevalent in the rainy and summer seasons with steadily rising trends in the winter season, though the numbers of severe and extreme drought events have shown fluctuation (Rahman et.al., 2017).

3.2.2 Projected Drought Hazard in the proposed districts and their neighbourhoods

Three General Circulation Models (GCM) have been employed by Islam et al., (2017) to understand drought hazard in Barind areas and their neighbourhoods. The results are compared with baseline, considering observed climatology. Three future scenarios are marked with different time scales. Standardized Precipitation Evaporation Index (SPEI) values are obtained by employing standard Hargreaves method for the estimation of drought in the project area and its neighbourhood. Figure 20 shows the probability density function (PDF) of the SPEI during the *Boro* paddy cultivating season in Bogura and Rajshahi (both districts are located in Barind tract) under current and future climate change conditions using a monthly time scale. Rajshahi and Bogura exhibit higher drought intensity in the future climate compared to the current period. The results show that the PDFs will move the upper tail continuously toward the mid-

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[7] A "extreme drought" is characterised by 45-70 percent crop loss (BARC, 2001)

[8] In a "severe drought" crop losses amount to 35-45 percent (BARC, 2001)

[9] A moderate drought occurs when crop losses amount to 20-35 percent (BARC, 2001)

[10] SPI quantifies the precipitation deficit for multiple time scales and reflects the impact of drought on the availability of different types of water resources.

[11] SPI-3 represents SPI calculated over three months, SPI-6 is calculated over six months and in 6 months and SPI-12 over 12 months.

century period and also shift to left side. This means that drought will be intensified in the North-west region in the future. Our proposed districts are under this region

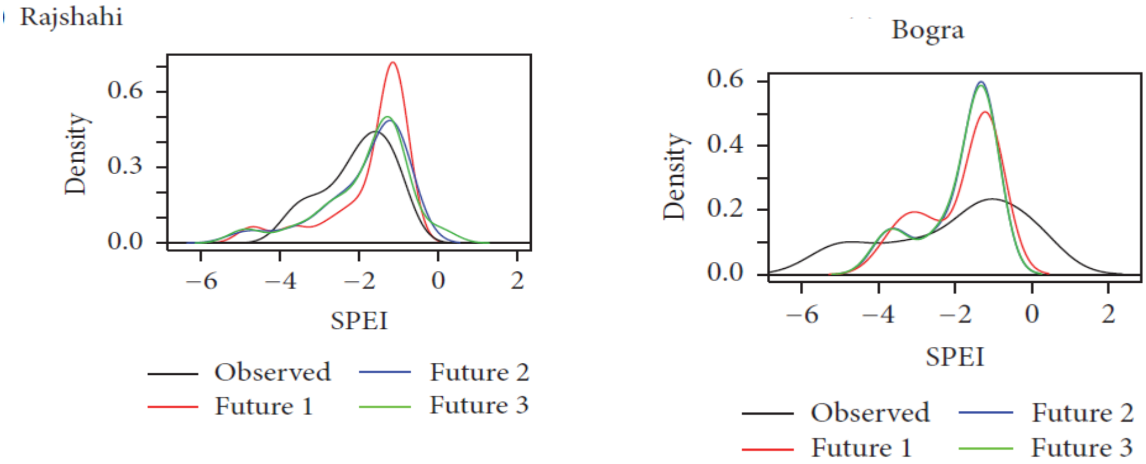

Figure 20: Probability Density Function (PDF) of SPEI for Rajshahi and Bogura districts

The future model 1 (CGCM3.1 GCMs)[12] and future model 2 (FGOALSG1.0 GCMs) indicate that frequency of extreme drought events (SPEI< −1) is expected to increase dramatically in the Western Bangladesh particularly in the North-west region (Islam et. al., 2017). It is worth mentioning that the risk of extreme drought events tends to increase in future climate conditions. Besides, drought frequency and intensity imply a steady increase from the current to mid-century periods, because the PDFs of SPEI values shift more than one and a half standard deviation, peaking at −1.5 in all the sub-regions of Western Bangladesh during that period. The PDFs of drought events will continue to move upward in future period compared to the current period (Islam et. al., 2017). The results demonstrate that the North-western region will increase a severe drought frequency and levels of intensity in comparison with the South-western region in the near future.

The spatial variation of drought in the context of present and future climate change for the Western part of Bangladesh was also studied by Islam et al., (2014) using SPEI. SPEI values were again estimated by using Hargreaves method. The highest average seasonal precipitation was observed in Rangpur (140.91 mm) during 2041-2050 while the lowest seasonal precipitation was found in Bogura (56.88 mm) during 2051-2060. However, Dinajpur demonstrated a decrease in precipitation by the period of 2041–2070 during 2051-2060 and 2061-2070 compared to the current period (1984-2013).

By using global climate models (GCMs) and the A1B scenario of the IPCC Special Report on Emissions Scenario for the 2041-2070 timeframe, it is shown that during the projected future period, the overall increase in PET is closely related to rises in temperature and surface net radiation that dominates in Bangladesh. Overall, the high drought hazards in the North-western region of Bangladesh are mainly due to the increased rate of PET, exceeding that of precipitation in changing climate (Islam et. al., 2014). The same projections show that potential

[12] Future Model-1, Future Model-2, and Future Model-3 indicate three General Circulation Models (GCMs). Future- Model 1 was developed by the Canadian Centre for Climate Modelling and Analysis (CGCM3.1), Canada. Future Model-2 was developed by the National Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics (LASG) and the Institute of Atmospheric Physics, China (FGOALS-G1.0). Future Model-3 was developed by the Hadley Centre Global Environmental Model, version 1 (HadGEM1).

drought hazard region will shift from the South-west to North-west part of the country in the near future.

3.2.3 Projected changes in precipitation and potential evapotranspiration

Figure 21 shows temporal variation in average PET and precipitation in the *Boro*[13] (winter) rice growing season for Western Bangladesh under the Special Report on Emission Scenario (SREP) A1B scenario. In the *Boro* rice growing season in North-western Bangladesh, in the baseline period (1984–2013) the annual average precipitation appears 67.20mm. The average *boro* rice growing season model-based projection precipitation are 94.95mm for the 2040s, 78.77mm for the 2050s, and 81.63mm for the 2060s. The average seasonal PET from January to May in the North-western region is expected to increase from 111.41 mm in the observed baseline period (1984-2013) to 147.63 mm for the 2040s, to 134.87mm for the 2050s, and 145.42 mm for the 2060s. In each of the future scenario periods, the projection PET are found to be higher than available rainfall, indicating moisture deficit for the most preferred crop *Boro* paddy. Moreover, the findings also indicate that with increasing climate forcing into the future, the moisture deficit from estimated PET will only increase if *Boro* paddy is continued to be cultivated under irrigated condition. The highest average seasonal PET is modelled in Rajshahi (170.35 mm) for the 2060s, whereas the lowest average PET is found in Rangpur (120.41 mm) for the 2050s (Islam et. al., 2017).

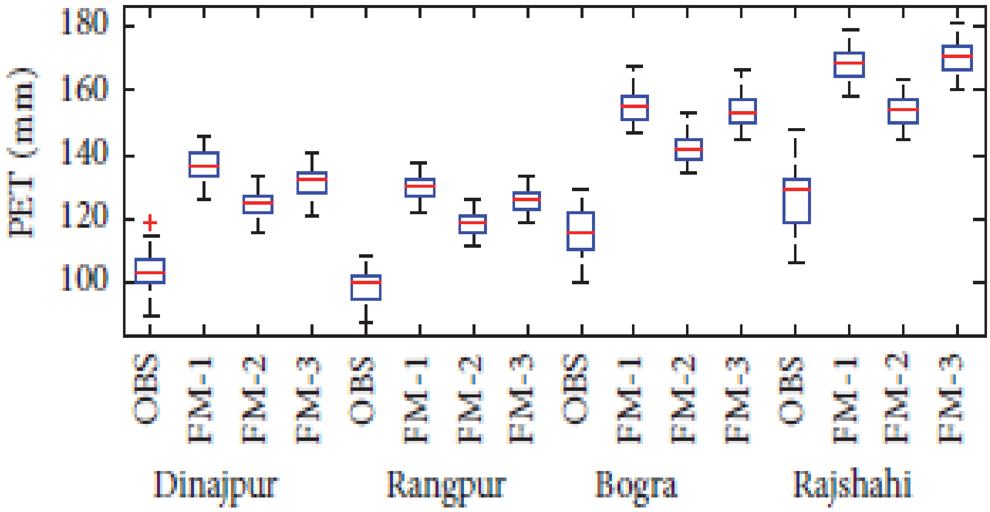

Figure 21: Changes in potential evapotranspiration in the north-western region[14]

The widespread increase in Potential Evapotranspiration (PET) is expected to rise with rising temperatures. It is to be noted that PET is always higher than available precipitation in North-western Bangladesh for different time periods, indicating that the precipitation is not offsetting higher levels of evaporation. Hence, drought conditions will only aggravate with increasing climate forcing.

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[13]*Boro* cropping season covers a period, generally from December to May.

[14] Islam, A.R.M.T., Shen, S., Hu, Z., and Rahman, M.A., 2017. Drought Hazard Evaluation in Boro Paddy Cultivated Areas of Wester Bangladesh at Current and Future Climate Change Conditions, ***Advances in Meteorology*** Volume 2017, Artle ID 3514381, 12 pages. https://doi.org/10.1155/2017/3514381.

4 Vulnerability of Communities to Climate Change Induced Drought

4.1 Vulnerability of Agricultural Production to Drought

The vulnerability of agriculture to climate change in Bangladesh, especially in the Barind region is primarily associated with an increase in unpredictability of rainfall and higher temperatures. By area, almost half (45%) of the farm production is exposed to this climate hazard, since it is fully rain-fed and depends entirely on the predictability of the seasons.

Historical account suggests that about 55% of the Barind areas was covered by forests in 1850 (Riches, 2008). As everywhere in the country, there has been a population boom throughout the twentieth century in the Barind, that caused conversion of lands under forest cover to cultivable lands. By 1970, 70% of the available lands have been brought under cultivation. Farmers had to rely on monsoon rains for the cultivation of *Aman* crop (i.e, rain-fed monsoon crop). During 1970s and 1980s, transplanted *Aman* (also rain-fed) rice used to be the main crop of the High Barind Tract (HBT). Farming households used to depend on such rain-fed crop for their livelihoods and nutrition. However, it requires a lot of water and is sensitive to changes in precipitation. Late onset monsoon delays its planting and affects germination while early termination of monsoon can cause crop damage, constrains harvests and grain filling (late-September to October). Drought as early as September and October drastically reduces the yield of this crop, and the chance of sowing/planting different rain-fed *Rabi* crops (winter crops) markedly decreases. Yield of *Aman* paddy and winter crops are markedly reduced during droughts. Table 4 shows reduction of yield by drought.

Table 2: Impact of drought on agriculture and crop production

Crops	(%) Yield Reduction			
	Slight	Moderate	Severe	Very Severe
T. Aman (rain-fed rice)	0-20	20-35	35-45	45-100
B. Aus (summer rice)	0-10	10-30	30-40	40-100
Wheat	0-40	40-50	50-59	59-100
Mustard	0-30	30-40	40-50	50-100
Potato	0-60	60-70	70-80	70-100

(T. Aman= Transplanted Aman, B. Aus= Broadcast Aus) *(Source: Ahmed, 2006)*

Following the severe drought episodes of 1978 and 1979, there have been state-led push for exploiting the dry season (i.e, January till late-May/early June; the pre-monsoon or *Kharif*-I cropping season) with the help of irrigation. Due to weak economic ability of farmers, various incentives and support services have been provided by the Government to popularize irrigated staple crops by exploiting GWT. With increasing farm profitability in doing so, and having the potential to go for two successive cereal crops in pre-monsoon as well as monsoon cropping seasons per year, farmers were lured to invest in irrigating equipment. By the early 1990s, the farmers in Barind areas adopted irrigated agriculture, thereby started to cultivate irrigated *Boro* paddy. While the coverage for *Boro* in the year 2000 in Barind was hovering around 0.1Mha, it increased to 0.15 Mha by the year 2015. Despite prevailing drought conditions, the lack of moisture was compensated by the application of irrigation.

The lack of water during drought is potentially the key hazard to cause vulnerability to agricultural production in the selected districts. Though National Agricultural Research Institutions (NARIs) in Bangladesh released different varieties of crops which are drought tolerant to a certain degree and maturing at shorter duration than usual, the farmers often have lack of information and experience on these varieties. Moreover, despite the growing concerns regarding net draw-down of GWT, farmers generally experience assured harvests of *Boro* as well as high yielding *Aman* once they can arrange GW-based irrigation. Therefore, there is a general reluctance to move away from usual predominant *Boro* paddy varieties such as BRRI-*Dhan* #28 and BRRI-*Dhan* #29. Because of these reasons, the farmers cannot adjust cropping patterns despite having a plethora of viable alternative crops and varieties that might save both climate change affected livelihoods and growing water stress.

About 55% of the land in the Barind region is irrigated by groundwater pumps installed by the Barind Multipurpose Development Authority (BMDA). This system has allowed many farmers to continually grow rice during the dry season and also through droughts. However, this system is not sustainable. Farmers continue to use crops that require a lot of water and the BMDA response to drought does not take into account the non-renewable nature of the aquifer, nor the impacts of climate change. As indicated in the earlier sections, GW is currently being used unsustainably and the GWT is gradually lowering at alarming rates, making it harder for farmers to abstract water for irrigation. BMDA have responded by increasing the number of deep boreholes and extending the area under irrigation. However, this is a maladaptive response that will eventually lead to the functional extinction of the aquifer and an agricultural catastrophe (see section 3.2).

4.1.1 Impacts of drought on agriculture

Apparently, drought is a managed hazard in Bangladesh. However, there are a few serious issues associated with it. Firstly, the resource available in the GWT is not automatically renewable, especially in the Barind area. An absence of irrigation water might reduce the *Boro* yield by 90%. Therefore, the apparently managed problem might no longer be manageable in the shorter term, which will only get aggravated under climate change.

Secondly, irrigation is also costly. The STW and LLPs being used by the farmers are run by either subsidized electricity, or by using diesel – the latter product again is heavily subsidized with an aim to facilitate food security of poor farmers. The BMDA deep TWs are run by electricity and also heavily subsidized. The environmental cost is also very high, since both the modalities of running TWs eventually release greenhouse gases directly, while the wet paddy production in irrigated agriculture also releases methane, a known greenhouse gas that has much higher global warming potential than carbon dioxide gas.

Thirdly, the social cost is also noteworthy. The lowering of GWT due to unsustainable operation of irrigation pumps gives rise to several social issues: (a) the hand TWs as the sources of potable water becomes inoperable, thereby giving rise to scarcity of drinking water at household levels; (b) the surface water bodies such as ponds and traditionally dug wells cannot offer water for bathing and washing of clothes for villagers when the water level goes down. This in turn affects hygiene and health condition of everybody, while lack of drinking water sources force women in drudgery; (c) women cannot grow vegetables in their courtyards, a traditional practice elsewhere for providing vitamin enriched food from own production, due to lack of water for sustenance of the vegetable plants during the dry period/summer; and (d) despite the fact that aquaculture is now a days a profit-making venture elsewhere, the disappearing water in the ponds imply that aquaculture is not a viable option for the supply of protein in household diet.

Perhaps, drought has its worst manifestation is the form of risking household food security in a farming community. Every three or four years, millions of hectares of land in Bangladesh are affected by droughts of different magnitude. Drought caused losses of BDT 10,569.20 million (US$141 million, BDT 75= US$1, at the 2015 exchange rate) between 2009 and 2014, of which more than 87% was from the crop sector. Although, the total loss in the crop sector was BDT 9,144.99 million (US$122 million) over this period, losses due to non-productivity of land that remained uncultivable due to drought amounted to an additional BDT 698.15 million (US$9.31 million) (BBS, 2015). The 1997 drought caused a reduction of around 1 million tons of food grain, of which about 0.6 million tons was from rice, entailing a loss of around US$500 million (Selvaraju et al., 2006).

Two of the major *Boro* (dry/pre-monsoon) rice producing areas of Bangladesh are the North-western and South-western regions, where drought affects 1.2 million hectares of cultivated *Boro* paddy fields during the dry season. The Ministry of Agriculture (MoA) of Bangladesh reported that moderate to very severe drought-prone areas accounted for about 56.9% of the country's total net cultivated area in 2012.The drought in the 1990s in North-western Bangladesh led to a shortfall of 3.5 million tons of rice. Between 1984 to 2013, 10 severe droughts occurred in these regions, which led to 70-75% fall in average crop production. About 70% of people in the proposed districts directly or indirectly depend on agriculture. Most importantly, more than 60% are small, marginal farmers and agricultural wage labourers who have suffered from food scarcity and nutritional deficiency due to these droughts.

In addition to rice, various winter and summer crops are affected by drought induced by long term absence of rainfall. For example, production of potato, wheat, maize, etc. is severely affected by drought. In many areas, cultivable lands remain fallow due to lack of rainfall or water.

4.1.2 Projected Crop Losses from Droughts

Drought prone areas in Bangladesh under a climate change scenario projection will be further affected in the dry season (Dastagir, 2015). The following possible consequences are projected under future climate scenarios: a sharp rise in evapotranspiration and diminishing rainfall will result in further reduction of river flow; increased consecutive dry days as well as decreased run-off will either limit irrigation or put increased economic constraints on economically poor farmers. Production of wheat, High Yielding Varieties (*HYV) aus* and *boro* rice varieties may no longer be economically viable (Dastagir, 2015). Moinuddin *et al.* (2011) reported that about 12,220 km² of land would be re-classified into the very severe drought class (i.e., lowest soil moisture level) as compared to the existing 3,639 km² (i.e., more than a three-fold increase in area) under severe changes in the climatic system during the *rabi* (winter) season. During the *Kharif-II* (summer and rainy) season, four times more area would be re-classified into very severe from the severe and moderate areas. The worst affected regions would be the North-west, the North-central and the South-west, where both irrigated and rain-fed crops are affected (Moinuddin *et al.*, 2011). As irrigation water demand escalates to mitigate drought conditions, increased water withdrawal from the already lean surface water systems could lead to further flow reduction in the rivers (Dastagir, 2015) and over-abstraction from ground water reserves, leading to its depletion.

4.2 Vulnerability of Water Resources

4.2.1 Household Water Use

The average per capita daily consumption of water for drinking, cooking, bathing, domestic washing, and toileting in rural areas of Bangladesh is estimated at 3.53, 6.71, 27.26, 12.18 and 12.75 litres (totalling an average of 62.43 litres/day/capita), respectively (Milton et al., 2006). As per population census in 2022, total population of Naogaon district is 2,784,598; Rajshahi 2,915,013 and Chapainawabganj 1,825,527 (BBS, 2022). The total population of the selected three districts is 7,525,138. So, current annual water consumption at household level is about 171.47 million m^3 (Mm^3).

For most of the population living in Barind area, shallow hand TWs used to be the only source of potable water. Owing to gradual decline in GWT, as indicated in the earlier sections, the shallow hand TWs become inoperable soon after the initiation of irrigation operation following transplantation of Boro paddy seedlings. As the local people have raised the issue in consultative meetings (please see Annex 25), people face scarcity of potable water starting mid-January. The situation continues till the mid-July, way past the harvest of Boro paddy, when sufficient recharge of GWT occurs. However, due to lack of adequate recharge in Upazilas such as Tanore, Mohanpur and Godagari of Rajshahi district, most of the hand TWs are found to be out of operation. This forces women to fetch water by accepting drudgery under scorching summertime sunshine and heat stress conditions.

Incidentally, while safe sources of drinking water are increasingly becoming challenging in Barind area, due to higher temperatures under climate change the heat index in the same area has been found to be increasing over the past few decades. A closer examination of average February Temperature in the area shows that the usual cold spells are no longer existing in the area and the February surface temperature has been steadily increasing in Barind. Figure-22 exhibits month-wise distribution of heat index estimated from long-term climatology for the Barind area, which clearly exhibits that the usual dip in the February heat index is no longer observed during decades of 1990s and 2000s as compared to 1980s.

People in the consultations/FGDs have indicated that they need more drinking water to get adjusted with the increasing heat. A combination of analysis of heat index and people’s claims indicate that under climate change, the potable water demand will increase in the 2030s.

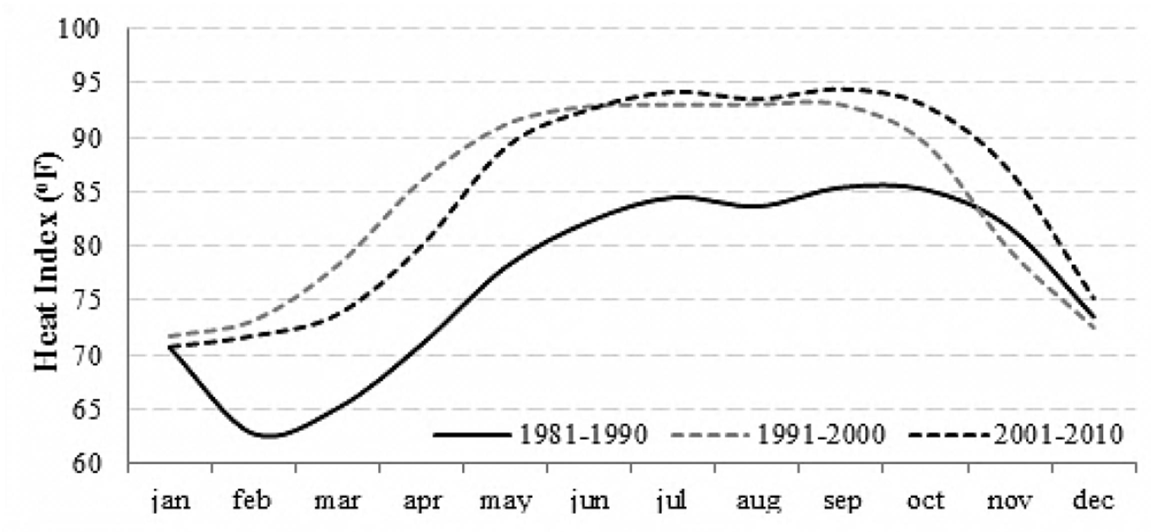

Figure 22: Month-wise and decadal change in Heat Index during the recent past

4.2.2 Agricultural Water Requirement and Use

Even under prevailing mild drought and subsequent water stress condition, *Boro* yield is likely to diminish over 90% in the Barind area. Based on water balance model of FAO, the water requirements for the following commercially important crops are estimated:

Rice/paddy	900 ~ 2,500 mm	Cotton	700 ~ 1,300 mm
Wheat	450 ~ 650 mm	Sunflower	350 ~ 500 mm
Maize	500 ~ 800 mm	Soybean	450 ~700 mm

Of course, the above range takes into consideration soil characteristics (such as moisture holding capacity), evaporation rates, moisture transport behaviour of specific crop and different varieties, etc. Ambient temperature, sunshine hours, wind speeds and available rainfall play significant roles in defining evapo-transpiration rates from specific standing crops. Rahman et al, (2019) has estimated crop water requirement for common varieties of paddy cultivars, averaging 4,783 m^3/acre (i.e, about 11,700 m^3/ha). The current irrigation coverage in Barind area is about 97%, involving 0.532 million hectare (Mha) cultivated area. This equates to a net crop water requirement of 6,038Mm^3 of water. Under climate change (using RCP 4.5 scenario for the 2030s), the farmers would require to provide about 6,500 Mm^3 water for irrigation in order to maintain the current level of *Boro* yield.

For a cropping pattern involving '*Boro* paddy-*Aman* paddy-fallow' (which is generally aspired for[15] in the Barind area), the farmers will require to apply irrigation and supplementary

[15] In reality, the only limiting factor is the availability and sustainability of the water resource needed for irrigation. The national agriculture system now has released several certified short-duration winter (i.e, Rabi) crop cultivars such as mungbean, mustard etc. that could be accommodated within the cropping pattern by adjusting timing for the cultivation of cereal crops. Since such Rabi crops are cash crops and generally their crop water requirements are very minimal compared to that for cereals (i.e, paddy), there exists great potential for such crops, which will eventually enable the country to achieve greater food self-sufficiency and import substitution – both being development goals of the government.

irrigation for *Boro* and *Aman*, respectively, in the order of 10,000 Mm^3 of water by 2030 in the Barind areas. In other words, if such a volume of water cannot be provided for irrigating the fields, the millions of farmers living in the Barind area will face serious food insecurity due to climate induced drought.

4.2.3 Groundwater Resources

In Bangladesh, groundwater resources are heavily exploited. Fortunately, in most part of the vast floodplain, the GWTs gets replenished due to excellent subsurface seepage and percolation and the presence of rivulets and rivers criss-crossing the landmass. However, as argued in the earlier sections, the recharge potential in the Barind, especially in the high Barind area, is not comparable with respect to that for the rest of the country. Two extreme trends are observed involving the GWT in any given hydrological year – a high water head during the wet season and a low water head during the dry season. The presence of both the phenomena implies that, while there is a loss of groundwater in the dry season, it is regained in the monsoon months with the occurrence of appreciable rainfall. The rise and fall of GWT therefore generally follows seasonal variability, while GW abstraction (mostly for irrigation) and recharge through rainfall play significant roles.

Aziz et al, (2015) report that recharge to the groundwater in the Barind area occurs mainly through infiltration of rainfall, stream and channel flow and percolation from pond and low lying areas. It is also understood that, minor contributions to recharge are generally obtained through return flow from irrigated fields and inflow from adjacent areas of higher elevation. Water table is found to be rising with the start of monsoon rainfall runoff. The water table reaches to the highest elevation at a minimum depth where GW is actually found. If the depth is found to be less, it implies that the elevation of GWT is high – the latter indicates good GW condition. Generally, the minimum depth of GWT occurs from July to September. In Barind region, the minimum depth is found to vary between 1m to 17m. The higher minimum depth is found in the Upazilas such as Tanore and Mohanpur of Rajshahi district.

In sharp contrast, the maximum depth of the GWT indicating deeper elevation below ground, generally occurring in the driest period (January to March) of the year. This coincides with heavy exploitation of the GW resources, mostly for irrigation purpose. Depending on geographic area and level of net GW abstraction, the maximum depth of GWT in Barind area is found within the range of 7m to 22m (Aziz et al, 2015). An analysis of well-based observation data in different Upazilas reveals that, the southern parts of the area exhibit lower maximum depth compared to the same for the northern parts of the Barind area. The recharge potential along the proximity of the Ganges river may be responsible for the replenishment, which is manifested in the reduced lowering of maximum depth of the GWT.

The lowering of GWT and its replenishment in Godagari Upazila during the monsoon deserves special mention as a case study. In Godagari, a time series analysis involving fluctuation of GWT from well data indicates that the rate of declining GWT faced a tipping point after 2009. The maximum GWT fell to 20.5m in 2013 from 17m in 2000, exhibiting a net decline by 3.5m. The corresponding minimum depth of GWT was 3m in 2000, which fell to 20m during 2013, indicating a net decline of 17m even after replenishments during successive monsoons. This warrants immediate interventions towards safeguarding the GWT. Figure –23 presents the decline of GWT in Godagari Upazila over time covering a duration of 2000-2013.

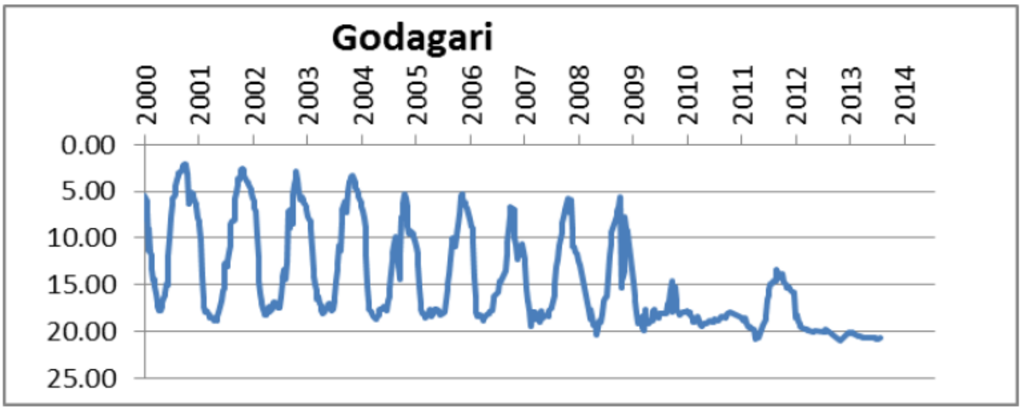

Figure 23: Hydrograph time-series involving GW abstraction well located in Godagari Upazila

Although similar trends are observed in Mohanpur, the extent of draw-down of GWT is relatively less than that for Godagari. The maximum depth went from 10.5m in 2000 to 15m in 2013, while the minimum depth of GWT went from 3m in 2000 to 14m in 2013. Therefore, even after monsoon rainfall induced replenishment, the extent of draw-down appears about 11m below ground!

In the project area, the groundwater table (GWT) reaches a maximum depth from April to May and regains its original position after the rainy season (September to October), suggesting that rainfall slowly percolates into the aquifer after some delay (Rahman et al., 2016, Hasda et al., 2020). Hasda et. al. (2020) showed that GWT's corresponding peaks (max) and troughs (min) follow rainfall episodes with a delayed response of 11.25–14.0 (avg. 12.73) weeks.

In general in Rajshahi, the annual average and annual minimum depth of water-levels (Below Ground Level, BGL) are influenced by SPI-3 monthly (SPI-3mo) values for the rainy season. The water-level depth (BGL) of a particular year is deeper than before and after this particular year with negative SPI-3mo values occurring in 1992, 1994, 1996, 2009 and 2010 and is lower with positive SPI-3mo values in 1991, 1993, 1997,1998 and 1999. The results show that the changes in SPI-3mo values coincided with the changes in the depth of water-level. The average water-level get deeper with a negative SPI value as less water is available to recharge the aquifer (Khan et al., 2008). However, after the year 2000 water-level depth (BGL) is continuously increasing even with the positive SPI values during successive rainy season. Therefore, there are other influencing factors on water-level depth (BGL) and these have very much influenced on water-level depth (BGL) along with dry episodes after the year 2000 in Rajshahi area. In Naogaon district, results also indicate that similar to the Rajshahi area changes in SPI value are related to corresponding changes in water-level depth and after 2007, water-level depths are continuously increasing (Islam et. al, 2017).

In Chapainawabganj district, the results indicate that negative SPI-12mo values coincide with deeper water-level depth (BGL) and vice-versa. However, since the year 2001 annual average water-level depth (BGL) has been continuously increasing even with the positive SPI values during the rainy season as in Rajshahi district. Hence, there are other influencing factors to determine water-level depth along with dry episodes following the year 2001 in Chapainawabganj area. Though there were few wet years after 1996 onwards, the minimum water-levels depths have not increased proportionately. Other factors come into play, suggesting that water-level depth (BGL) is also influenced by water management practices and changes in cropping patterns (Islam et. al, 2017). Thus overall results suggest that, if predominant cropping patterns are grossly maintained, water-level depth (BGL) is influenced by rainfall-induced recharge, and hence by drought, which have implications for sustainable groundwater management schemes.

The average GWT gets deeper with a negative SPI values as less water is available to recharge (Khan et al., 2008). However, after the year 2007, depth to GWT is continuously increasing even with the positive SPI values during the rainy season's months. Therefore, there are other influencing factors on GWT depth, which compound the effects of drought after the year 2007.

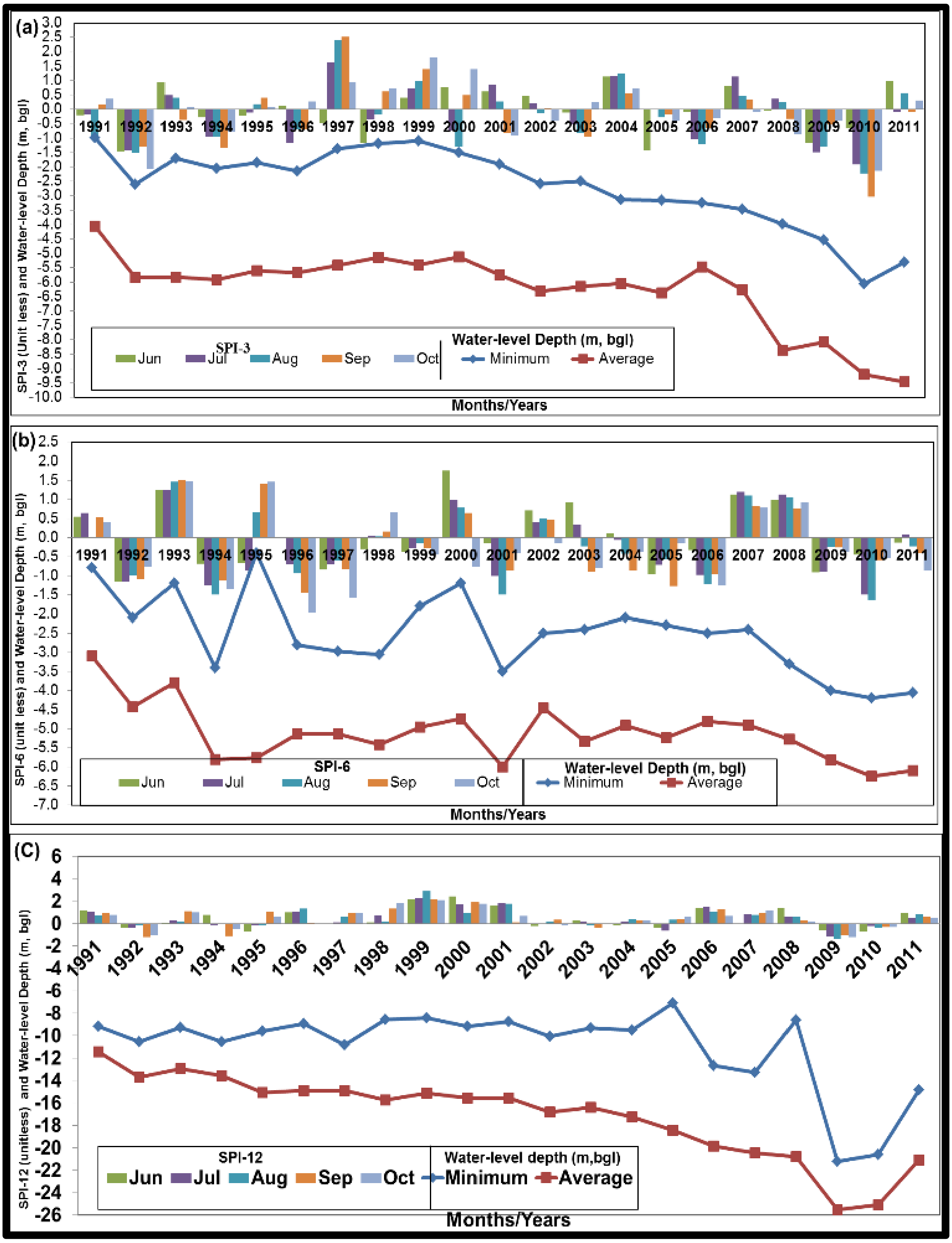

Figure 24: Comparison of annual average changes in groundwater depth and SPI values for rainy season (Jun-Oct): (a) SPI-3mo and groundwater depth of Rajshahi district, (b) SPI-6mo and groundwater depth (m, BGL), and (c) SPI-12mo and groundwater depth.

Jahan *et. al.*, (2015) pointed out that due to high elevation (22–47 m AMSL), undulatory land mass with highly regular to irregular topography and high drainage density of the Barind Tract, the land is unable to hold rainwater adequately and thus loses it as run-off water, and ultimately water flows through canals (*Kharies*) and ultimately into major rivers like Purnabhaba, Mahanada, Atrai, Padma (Ganges). Besides, 58% area of the Barind Tract has low to very low groundwater potentiality for abstraction for drinking and agricultural purposes (Rahman et al., 2018). Infiltration capacity of the Tract is also low (2–3 mm/day) due to clay soil characteristics (Barind Clay of Pleistocene age) (Jahan et al., 2010a). Thus recharge ground water is constrained (Jahan et al., 2015; Jahan et al., 2010b; Rahman et al., 2016). Finally, it may reveal that the meagre allocation of rainfall, recurring drought effect, soil moisture deficiency, surface water scarcity and ground water development result and high demands lead to over exploitation of this fragile resource.

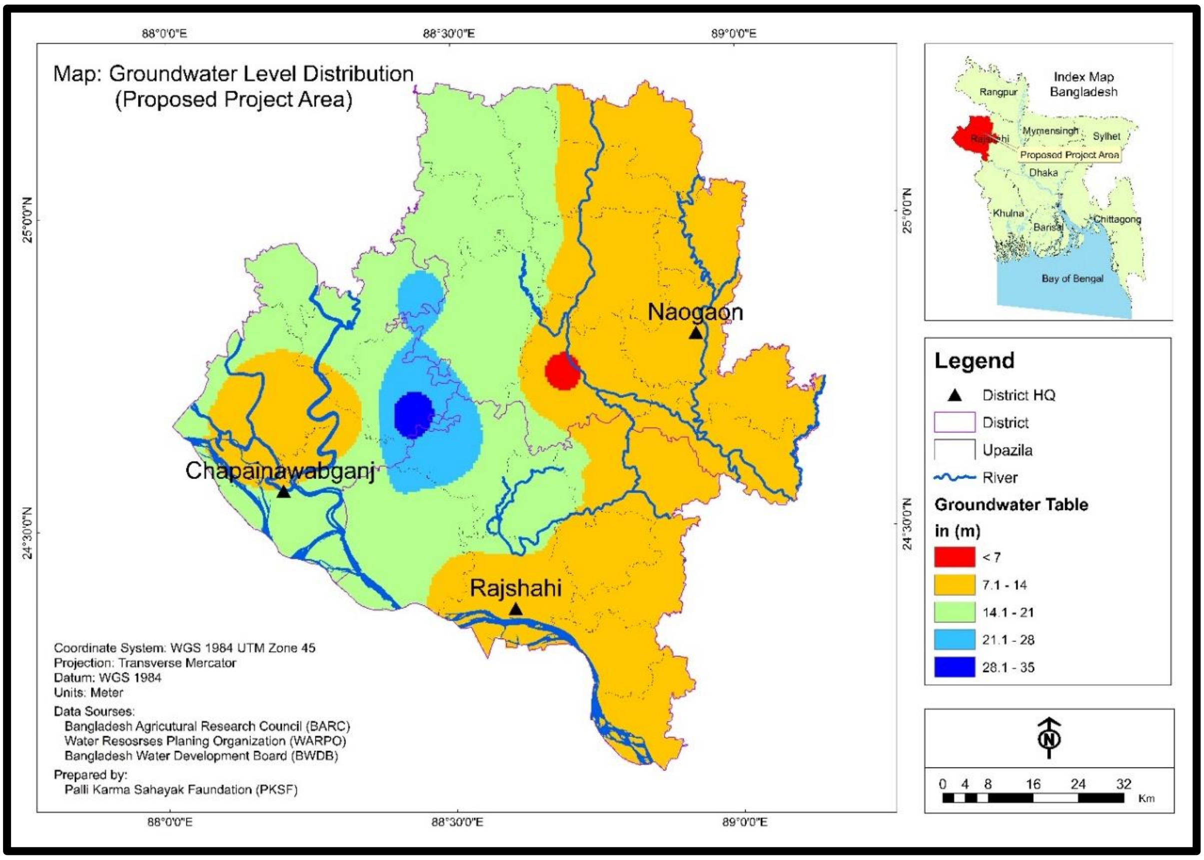

Figure 25: Ground water level distribution in the proposed project area

4.2.4 Water Balance in the Project Area

BMDA has run a water balance metamodel for the Barind area. From annual rainfall over an area of 7,500 km^2, about 12,000Mm^3 water is obtained per annum. It is estimated that, about 35% of available rainfall (assuming about 1,600mm/year) is lost as runoff through the rivulets and rivers. This runoff amounts to 4,200 Mm^3 water. About 14% or 1,680 Mm^3 water is restored as soil moisture through infiltration processes. Recharge as a natural process accounts for about 5% of rainfall, amounting to a meagre 600 Mm^3 water. Direct evaporation from surface sources accounts for an estimated amount of 5,560 Mm^3, which is added by evaporation induced by irrigated agriculture (i.e, evapo-transpirative loss) in the tune of an additional 24% or 2,880 M Mm^3 of water. The model output reveals that the total water demand (including various losses through direct evaporation, evapo-transpiration from irrigated crops, percolation and infiltration and runoff through river systems) is in the order of 14,880 Mm^3 as against availability from rainfall is around 12,000 Mm3.

The above water balance model output clearly demonstrates that there is already a deficit of about 2,880 Mm^3 of water, which is met by overexploiting the GW aquifer system. Under climate change, the RCP4.5 scenario for 2030s suggest that, an additional 422 Mm^3 water will be needed to offset evaporative demand that is likely to be aggravated by climate change. If this is further compounded by a net reduction of rainfall during the winter and pre-monsoon (coinciding with *Rabi* and *Kharif*-I cropping seasons), the total deficit might cross an additional volume of 650 to 700 Mm^3 of water on top of the current deficit of 2,880 Mm^3.

The results of early days of water deficits are exhibited in histograms presented in various figures. In order to sustain food security with continued irrigation in Barind area, thereby defying climate change induced increased drought, not only the farmers need to accommodate alternative crops that demand lesser volumes of water (and still remain culturally and economically suited for the society), there must be an effort towards harvesting and reusing water by temporarily storing in surface sources as well as by artificially recharging the aquifer, using the runoff water as much as possible. Since an estimated amount of 4,200 Mm^3 water escapes the Barind region as runoff, effort must be made to assist recharge of at least 65 to 70% of the runoff water.

4.2.5 Vulnerability of Households to drought

Livelihoods

High poverty, natural resource-based livelihood, lack of adequate information on climate change and a lack of specialised institutions for addressing climate change are the key vulnerabilities that affect the Barind people. A study conducted by BCAS (2010) showed that 45.6% of households are either very poor (19.1%) or poor (26.5%) who are absolutely landless having inadequate income for meeting their basic needs, i.e., food, health, housing and education. Findings indicate that the percentage of households belonging to marginal and medium wealth categories are 19% for each category, while only 4% are rich or very rich.

70% people of the region are engaged in crop production (BCAS, 2010). It is also found that 36.5% of the households cultivate their own land whereas 26.2% and 7.6% sell their labour to others or are sharecroppers, respectively (BCAS, 2010).

Distribution of occupation by different wealth categories shows that the main occupation of the marginal, medium, and rich household heads is agriculture, whereas the very poor and poor household heads' main occupation is agricultural wage labour, sharecropping and fishing. The percentage of marginal, medium, and rich households engaged in agriculture is 49.6%, 68%, and 68.7%, respectively. On the other hand, 51.4% and 37.4% of the very poor and poor households are engaged in agricultural wage labour, respectively. Non-agricultural wage labour is also represented by the very poor (11.7%) and poor (8.5%) households. Service is represented by 10.3% and 14.9% of the medium and rich household heads, respectively. This distribution of occupation implies that the very poor and poor households are highly dependent on daily wages from the agricultural sector which is highly vulnerable to climate change.

Bangladesh Bureau of Statistics (BBS) carried out an analysis of the impacts of various disasters for the period of 2009-2014. The analysis shows that 25.39% of the households (HHs) of Barind tract were affected by drought compared to the national average of 14.80%. Over the 2009-2014 period, 8.7% of the households did not have any work or income.

The effect of drought is often disproportionately felt by women. Often the GWT becomes so low due to the effects of drought and excessive abstraction of water for irrigation that hand tube-wells/shallow tube-wells and sometimes deep tube-wells do not work. In these cases, (mostly) women are forced to collect drinking water from sources that are typically 3 to 5 km away from their homes. Spending 2 to 3 hours in doing so hampers their normal lives and livelihoods. There is an associated opportunity cost to this since women could spend this time educating their children or doing income generating activities. If we consider the minimum labour wage rate in the area which is BDT 400-500 per day, they lose BDT 100-150 (US$1.20 to 1.50) per day as foregone income.

Health

Drought severely affects the sources of irrigation and drinking water by depleting the ground water table and drying up ponds and canals. As a result, waterborne diseases (diarrhoea, dysentery, etc.) occur at a higher rate and household expenditure increases. Survey results (BCAS, 2010) show that safe drinking water sources of 59.2% households were negatively impacted by drought, of which 57%, 31%, and 20% were affected at moderate, low, and severe levels, respectively.

The BBS data also shows that 56,920 HHs (133,610 people) in Barind tract suffered from various diseases due to insufficient drinking water and other use of water from 2009 to 2014. The major diseases are diarrhoea, dysentery, skin disease, flu cough, fever, jaundice, etc.

Outbreaks of waterborne diseases and health problems like diarrhoea and dehydration in the dry season are common in the Barind area and add stress to household finances. Skin disease due to lack of water was also found to be severe during dry season in the project areas. Data reveal that 77% of the households claimed that their health was affected by drought, of which 85% and 15% were affected at low and moderate levels, respectively.

Knowledge as a Key Indicator of Adaptive Capacity

There appears to be growing agreement that knowledge represents an important determinant of adaptive capacity (Williams et al., 2015). Knowledge also features prominently at the policy level, and the IPCC considers a ‘lack of knowledge’ to be a possible constraint on adaptation. Furthermore, since the Marrakesh Accords in 2001, most international frameworks for capacity building related to climate change have emphasised the importance of producing and sharing high-quality knowledge. Knowledge can be measured either as an input, such as access to information or as an output, such as actions taken through a new understanding, or both.

The BBS data show that only 14.07% of HHs in Barind tract have knowledge and perception of climate change. Among them, 7.87% have knowledge and perception of long term climate change, whereas only 1.62% perceive regional changes in temperature/rainfall, and 1.92% are aware of sudden extreme events affecting human life. This means, there is lack of knowledge and understanding of drought affected community about climate change.

Knowledge of climate change is important to adapt to the changing situation. Without knowledge and information, they become unable to identify current and future problems related to changing situation of climate. Hence, they fail to make appropriate decisions that will improve their long-term wellbeing.

5 Policy landscape and governance

5.1 Climate Change Policy and Strategies in Bangladesh

Bangladesh has two major strategies to deal with climate change: the National Adaptation Programme of Action (NAPA) 2005 (updated in 2009); and the Bangladesh Climate Change Strategy and Action Plan, 2009(BCCSAP, 2009). NAPA 2005 was formulated with the strategic goal and objective of reducing the adverse impacts of climate change (UNDP, 2016). However, NAPA 2005 considered urgent and immediate priorities for adaptation and engaged sector-based line ministries (Alam et al., 2011).

5.1.1 National Adaptation Programme of Action (NAPA), 2009

NAPA has been formulated in 2005 to address immediate and urgent adaptation needs of the country. It was updated in 2009with new knowledge and information. The Updated NAPA has identified short, medium, and long-term adaptation interventions to address climate change. NAPA has identified adaptation options by various sectors including research and knowledge management; agriculture, fisheries and livestock; human health, resilient infrastructure, disaster management, livelihood, biodiversity, policy and institutional capacity building, etc. But the adaptation measures should be ecosystem-specific since impacts of climate change vary by ecosystem. For example, adaptation measures for crop agriculture in flood plain ecosystems are not similar to that of the seasonally dry Barind ecosystem. NAPA has also identified roles and responsibilities of institutions for implementation of identified adaptation options. It has proposed government ministries and departments for implementing different adaptation measures.

5.1.2 Bangladesh Climate Change Strategy and Action Plan (BCCSAP)

In 2008, MoEF prepared the BCCSAP prior to the UK-Bangladesh Climate Change Conference in London. This BCCSAP was revised and adopted by the government in July 2009. It provided a ten-year programme for capacity and resilience building in the country to meet the challenge of climate change. It is the key strategy document to address climate change including both adaptation and mitigation options. The BCCSAP has identified 44 programmes under 6 thematic areas. The thematic areas are: 1) Food security, social protection and health; 2) Comprehensive Disaster Management; 3) Climate resilient infrastructure development; 4) Mitigation and low-carbon development pathway; 5) Capacity building; and 6) Research and Knowledge management. The proposed project will comply with thematic area 1, 5, and 6. ‘Adaptation to drought’ is considered a major programme under thematic area 1. Besides, thematic area 5 suggested capacity building of government and non-government institutions at national down to local level. The proposed project will also generate knowledge on climate change issues, particularly on adaptation to climate change induced drought, which comply with thematic area 6. Though BCCSAP focuses on research and knowledge management regarding climate science and technologies, it does not address measuring effectiveness and efficiency of the adaptation measures towards increasing resilience of the vulnerable community.

Though a programme is proposed for adaptation to drought, the BCCSAP did not present detailed vulnerabilities to climate change induced drought in Bangladesh. It did not identify drought vulnerable sectors and impacts of climate change on those sectors. Hence, it is not possible to understand specific adaptation measures for drought vulnerable communities from this document.

5.1.3 Third National Communication (TNC) of Bangladesh

As a signatory of UNFCCC, Bangladesh has obligatory to submit adaptation and mitigation plan and achievement to the UNFCCC. The TNC has two major parts. Part 1 is on the mitigation and part 2 is on the adaptation. 'Adaptation' part covers the concept of this project proposal and analyses of climate change in the national context, its impacts and vulnerabilities and suggested probable adaptation measures. Most importantly, this policy document analysed ecosystem specific and sector specific impacts of climate change. It recognises that though flood and cyclone are the two most visible and frequent natural disasters, severity of drought is also significant in terms of water security and crop production. Hence, the document puts significant emphasis on adaptation to drought. It provides emphasis on surface water management for adapting to drought. Re-excavation of ponds and canals and sustainable use of ground water are suggested as priority adaptation measures. The policy document has also recognised institutional roles for addressing drought. The TNC recognised that the Barind Multipurpose Development Authority (BMDA) is the key institution to address drought particularly in the North-west region.

5.1.4 Delta Plan 2100

Delta Plan 2100 is an integrated long-term sustainable development plan of Bangladesh. The plan critically analysed the country context in terms of physiographic, socio-economic, and environmental situation. It has elaborately described past investments and lessons. The plan carried out institutional mapping which identified roles and responsibilities of various government and non-government organisations. The fundamental task of the plan is that it has developed baseline of different sectors including water resources, climate change, agriculture, livelihood, etc. Climate change is significantly integrated in the Delta Plan 2100. Adaptation to climate change has been given priority in the Delta Plan. It identified 6 hotspots in Bangladesh due to climate change impacts. Barind and drought-prone areas is one of them. Most importantly, the delta plan has established baseline of water resources in the country which is important for this project. But it did not provide an estimate of availability of ground and surface water particularly for the Barind area.

5.1.5 National Agriculture Policy

The Government of Bangladesh developed the National Agriculture Policy in 1999 for the first time with an aim to increase food production in a sustainable manner. It focused on extension of new varieties, irrigation, sustainable land use, promoting IPM, etc. This policy was revised in 2013. In these revisions, the policy adopted disaster risk reduction and climate change adaptation and mitigation approach along with improved water management and development and extension of new varieties of climate-resilient crops. Thus, climate change has been an integrated part of the national agriculture policy. The policy again was revised in 2018. The new agriculture policy has given emphasis on investment including quality seed production, fertiliser and irrigation management, biotechnology, farm mechanisation, agriculture cooperative and marketing, women empowerment in agriculture, natural resource management, specialised agriculture, regional special agriculture, involvement of the youth force, agriculture rehabilitation, agriculture afforestation, safe and nutritious food production, use of information, and communication technology. The newly approved policy has prioritised enhancement of productivity, coordination of different ministries and organisations with the agriculture ministry, and use of knowledge and expertise both in private and public sectors.

The agriculture policy has also given priority to coastal agriculture, *haor*[16] and wet land, hill agriculture, Barind agriculture, char land agriculture. Natural disaster and agriculture rehabilitation, flood, extreme temperature, cyclone, high and low tides, drought, thunderbolt, submergence and salinity have also been addressed by the policy for taking appropriate steps both from research and farmers level to avoid productivity loss.

5.1.6 National Environmental Policy, 2018

National Environmental Policy was prepared in 2018 to adequately address the issues concerning improving the environment in an integrated manner. Section 3.5 "Water Development, Flood Control and Irrigation" of the policy is related to the present study. The Policy directives of this section are given below:

- Ensure environmentally sound utilisation of all water resources.
- Ensure that water development activities and irrigation networks do not create adverse environmental impacts.
- Ensure that all steps taken for flood control, including construction of embankments, dredging of rivers, digging of canals, etc. be environmentally sound at the local, zonal and national levels.
- Ensure mitigation measures of adverse environmental impact of completed water resources development and flood control projects.
- Keep the rivers, canals, ponds, lakes, *haors*, *baors* and all other water bodies and water resources free from pollution.
- Ensure sustainable, long-term, environmentally sound, and scientific exploitation and management of the underground and surface water resources.
- Conduct Environmental Impact Assessment before undertaking projects for water resources development and management."

This policy mainly focused on conservation of environment while implementing infrastructure-based water management. But it does not explicitly address climate change impacts on water resources in the country. There is, therefore, a need for a new policy document on sustainable water management in the drought affected Barind region.

5.1.7 The National Water Policy (NWPo), 1998

The National Water Policy (NWPo) was the result of a series of comprehensive consultations and debates, involving both the public and private (NGO) sectors. The main objectives of the NWPo are:

- To address issues related to the harnessing and development of all forms of surface water and ground water and management of these resources in an efficient and equitable manner.
- To ensure the availability of water to all elements of the society including the poor and the underprivileged, and to take into account the particular needs of women and children.

[16] Bowl shaped low area that remains under water for about six months in a year.

- To accelerate the development of sustainable public and private water delivery systems with appropriate legal and financial measures and incentives, including delineation of water rights and water pricing.
- To bring institutional changes that will help decentralise the management of water resources and enhance the role of women in water management.
- To develop a legal and regulatory environment that will help the process of decentralisation, sound environmental management, and improve the investment climate for the private sector in water development and management.
- To develop a state of knowledge and capability that will enable the country to design future water resources management plans by itself with economic efficiency, gender equity, social justice and environmental awareness to facilitate achievement of the water management objectives through broad public participation.

The new policy emphasises the improved use of existing resources, public participation and increased emphasis on management and knowledge, in addition to water resource development.

5.1.8 The National Water Management Plan (NWMP, 2004)

The National Water Management Plan (NWMP), which was finalised in 2001 and formally approved in 2004, is the first plan to be developed after the NWPo was issued and reflects the integrated water resource management approach laid down in the NWPo. The NWMP consists of a series of main documents, supporting annexes and a National and Regional Investment Portfolio. The preliminary results of the NWMP are derived principally from the Water Resources Planning Organisation (WARPO) database, expert consultations. The preliminary results and the FAP studies were initially discussed in two successive rounds of public consultations (in 24 locations in the first round and 28 locations in the second round). The NWMP has 84 programs under eight clusters: i) Institutional development, ii) Enabling environment, iii) Main rivers, iv) Towns and rural areas, v) Major cities, vii) Disaster management, viii) Agriculture and water management, and viii) Environment and Aquatic resources. However, these programs particularly support the infrastructure and government agencies do not have the access and institutional capacity to support rural poor and ultra-poor at grassroots level for addressing their adaptation needs. The water management plan should be ecosystem based because both quality and quantity of water vary greatly by ecosystem.

5.1.9 National Strategy for Water Supply and Sanitation

The National Strategy for Water Supply and Sanitation (NSWSS) was adopted in December, 2014 as an integral part of the Sector Development Plan (SDP) 2011-2025. It aims to ensure safe and sustainable water supply, sanitation and hygiene services for all, leading to better health and well-being. The strategy is based on 13 guiding principles which include 1) Regard water supply and sanitation as human rights; 2) Consider water as a public good that has economic and social value; 3) Ensure drinking water security through integrated water resource management; 4) Promote water supply, sanitation and hygiene components in all WASH development programs in an integrated manner; 5) Adopt a participatory, demand driven and inclusive approach in all stages of WASH service delivery programs; 6) Recognize importance of gender in all WASH activities; 7) Ensure equity in services by giving priority to arsenic affected areas, hard-to-reach areas, water-stressed areas and vulnerable people; 8) Protect human health and water supply and sanitation facilities from the adverse impact of natural and manmade disasters and climate change; 9) Harness the potential resources from solid and liquid wastes; 10) Promote innovations to address technical and social needs; 11) Promote transparency and accountability at all stages of service delivery; 12) Undertake a gradual approach to improve the quality and service levels and 13) Promote enhanced private sector participation. Guiding principles 7 and 8 are closely linked to this strategy i.e., the project will contribute to achieving goal of the strategy by addressing people living in remote and vulnerable areas and integration of disaster of climate change in the water supply and sanitation practices for ensuring sustainability.

5.1.10 Other national policies and climate change

The Perspective Plan (PP) is the ‘Blueprint that advances a more inclusive and holistic picture of development that considers climate change in devising strategies for overall and sectoral development plans and proposed ‘Climate Change Response Options’. Other national sectoral policy documents such as the Coastal Zone Policy, 2005 and the Agriculture Policy, 2010 are currently being reviewed taking into account the effects of climate change and policy directions to combat those. Bangladesh Sixth FYP-2011-2015 provides strategic directions and a policy framework as well as sectoral strategies, programmes and policies for accelerating growth and reducing poverty. The Sixth FYP has identified benchmarks, targets and implementation strategies for the period it covers. The Seventh FYP (2016-2020) has reviewed Climate Change and Disaster Risk Reduction, taking into account gender issues (Background document 17 of Seventh FYP).

5.2 Climate change governance and mainstreaming activities

Climate change impacts are cross-sectoral and thus different ministries of Bangladesh are concerned with both the immediate and the far-reaching consequences of climate change. These consequences are dealt with mainly by incorporating climate change challenges into sector policies and ensuring that institutions deliver necessary services. The Ministry of Environment, Forests and Climate Change (MoEFCC)[17] has been playing the leading role in managing climate change and the challenges Bangladesh faces.

The 2013 Climate Public Expenditure and Institutional Review (CPEIR) Study provides details on climate change governance structure and processes by focusing on related policies and institutional frameworks. The policy frameworks provide strategic planning and the proposed necessary institutional architecture to implement climate actions. Initially, an attempt was made to mainstream climate change issues within a disaster risk management framework, namely the Comprehensive Disaster Management Programme (CDMP I), under the auspices of Ministry of Disaster Management and Relief (MoDMR) framework, i.e., Component 4b. It aimed to establish a mechanism that would facilitate the management of long-term climate risks as an integral part of national development planning. Later, with the addition of the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009, a gradual transfer of climate change-related risk management took place from MoDMR to Ministry of Environment, Forests and Climate Change (MoEFCC). Currently, MoDMR with its sub-agencies, such as the Department of Disaster Management (DDM) and the Cyclone Preparedness Programme (CPP), is focusing on Disaster Risk Reduction (DRR) aspects. Simultaneously, MoEF with its major sub-agencies such as the Department of Environment (DoE) and the Forest Department has its primary focus Climate Change Adaptation (CCA) issues.

[17]In 2018, the Ministry of Environment and Forest (MoEF) changed to Ministry of Environment, Forest and Climate Change (MoEFCC).

The recently completed multi-donor funded CDMP II (implemented under the supervision of MoDMR) invested in climate change aspects and implemented partnership programmes with 12 Ministries, 13 agencies and also some non-government organisations. These partnership action programmes could also be considered as mainstreaming relevant climate change issues into the regular development programmes of the respective ministries.

6 Previous and ongoing efforts/interventions, results and gaps

6.1 On-going activities

6.1.1 Activities of Barind Multipurpose Development Authority (BMDA)

BMDA is the sole authority in the Barind Tract region for promoting integrated development of the Barind ecosystem. Initially, BMDA was a project titled “Barind Integrated Area Development Project (BIADP)” of the Bangladesh Agriculture Development Corporation (BADC). The project was started in 1986 with the aim of development of ground water for irrigation. With continuous success of installation of deep tube-wells, the government of Bangladesh established BMDA integrated development of the Barind region. BMDA has implemented needs-based development programmes aimed at improving socio-economic conditions of the people and protecting environmental balance in the Barind Tract.

As of September 2019, BMDA has installed 11,703 deep tube-wells and re-activated 4,221 ponds; installed 217 low-lift pumps; constructed 15,789 irrigation water distribution systems; re-excavate 1776 km canals; constructed 722 cross dams, etc. All of this water infrastructure brought 296,139 hectares of *Boro*[18] field (winter rice), 248,717 hectares of *Aman* field (rain-fed rice), 37,191 hectares of *Aus* (summer rice) & 209,574 hectares of other crop fields under irrigation in the whole Barind region (16 districts). It has provided training to 142,947 farmers so far on water management, cultivation of new crop varieties, etc. BMDA also promotes drinking water in the water-scarce villages through water supply from deep tube-wells and dug-wells. BMDA constructed 1475 water supply networks (micro-scale) and excavate 145 dug-wells. BMDA is also currently implementing projects related to improved seed production, supply, and farmers’ training; efficient irrigation infrastructure; rehabilitation of old deep tube-wells and a system based on smart cards for water pricing.

The BMDA project of deep tube-wells, although comprehensive and implemented effectively, is maladaptive to climate change. It has not considered the effects of increasing drought conditions in the region and the increasingly excessive dependence on aquifers through the deep tube-well project. In order to make the BMDA project adaptive to climate change, it must 1)increase water use efficiency as demands increase, 2)increase the storage capacity of rain harvesting either above ground or within aquifers – in order to balance abstraction with recharge so that the semi-renewable GW resource is not depleted.

6.1.2 Bangladesh Weather and Climate Services Regional Project:

The government of Bangladesh has approved a project on “Bangladesh Weather and Climate Services Regional Project (BWCSRP)” in February 2017 with financial support from the World Bank. Bangladesh Meteorological Department (BMD), Bangladesh Water Development Board (BWDB) and Department of Agricultural Extension (DAE) are jointly implementing the project.

Department of Agricultural Extension (DAE) under the Ministry of Agriculture is implementing “Agro-Meteorological Information Systems Development Project (Component-C of BWCSRP). The objective of the project is “to strengthen the capacity of the Government

[18]*Aus*-summer rice, *Aman*-rain fed rice, *Boro*-winter rice.

of Bangladesh to deliver reliable weather, water and climate information services and improve access to such services by priority sectors and communities”.

Under this project, DAE is disseminating district-wise early warning information on its websites. The lead time is 5 days. The early warning message contains 5 days’ forecasts of rainfall, temperature, humidity, wind speed and direction, etc. The message also provides suggestions on crop management during this time. The proposed project will establish a linkage between its participants and the early warning system so that farmers can get helpful information for crop management.

6.1.3 Ecosystem-based Approaches to Adaptation (EbA) in the Drought-prone Barind Tract and Haor Wetland Area Project

The title of the project is “***Ecosystem-based Approaches to Adaptation (EbA) in the Drought-prone Barind Tract and Haor Wetland Area Project***”. Sponsoring ministry is the Ministry of Environment, Forests and Climate Change (MOEFCC), while Department of Environment (DOE) is the implementing agency.

Objectives of the project are: (1) to increase the capacity of the government and local communities living in the Barind Tract and the Haor areas; (2) to reduce negative effects of climate change using ecosystem-based adaptation (EbA). The project received financial support from GEF and UNEP. The total financial mobilization is in the order of USD 5.2 million.

The project is being implemented (2019-2025) in two ecosystems, one of which falls in Barind Tract. In the drought-prone ecosystem, the project aims at the following activities:

The following are the intended activities under the project: Re-excavation of *khals* and ponds (by BMDA), afforestation and reforestation (Bangladesh Forest Department), rainwater harvesting (by BMDA), training on EbA for the community, local government officials and government officials (joitly by DOE, DAE and BMDA), quick-growing orchard establishment (by DAE), farming/gardens (DAE+BMDA) and spice cultivation (by DAE).

A total of 12 km *khals* and as many as 19 ponds will be brought under re-excavation, enabling to capture rainwater and help supplementary irrigation and maintenance of orchards/vegetable gardens. In addition, 27 rain water harvesting systems will be established under the project. It is expected that, by doing the above, the project will contribute to the sustenance of ecosystems in the drought affected selected sub-districts and help people adapt to climate induced droughts better.

6.2 Past projects

6.2.1 Community Climate Change Project

Bangladesh is one of the leading countries in the world combating climate change with its own financial resources as well as support from various development partners. The Government of People's Republic of Bangladesh successfully sensitised the developed countries (those are mainly responsible for climate change and global warming) by establishing Bangladesh Climate Change Trust Fund (BCCTF) with public money for implementing the 2009 Bangladesh Climate Change Strategy and Action Plan (BCCSAP). Influenced by the initiative of the Government of Bangladesh, the development partners established Bangladesh Climate Change Resilience Fund (BCCRF) in 2010 to support the government in implementing the BCCSAP. As per the BCCRF policy, 10% of the money should be implemented by Non-government Organisations (NGOs). The governing body of the BCCRF entrusted the PKSF to implement the NGO window of the BCCRF under the name of Community Climate Change Project (CCCP).

The activities of the project are mostly climate risk specific. These activities were mainly proposed by the vulnerable communities of the selected areas. The CCCP added simple management technologies or improved the management system of those activities to make them climate resilient. For example, the CCCP provided technologies like slatted houses for goat rearing, poultry houses for duck and hen rearing, plastic boxes for crab fattening, etc. in order to protect the livelihood assets of the selected vulnerable people from the adverse impacts of climate change and associated extreme events. The project emphasised on climate-resilient homestead development and safe drinking water supply for the poor and vulnerable communities. The CCCP adopted a cluster-based approach for raising homestead plinths of the flood-vulnerable and coastal communities. The CCCP provided different types of water technologies in the three different risk zones to increase access to safe water for drinking, household usage, and irrigation. The project provided shallow tube-wells in the flood-prone areas, submergible tube-wells in the drought-prone areas, and deep tube-wells, rainwater harvesting plants, desalination plants, Pond-Sand-Filter (PSF) with ponds, etc. in the salinity-prone areas. In addition, the CCCP provided training to about 500 staffs and 43,000 project participants on climate change issues.

This project found that there was a fundamental lack of appropriate organisations for addressing the adverse impacts of climate change. Government institutions do not have the human resources required for intervention at the community and individual levels and although Micro-finance Institutions (MFIs) traditionally have a very strong presence at the community level, they do not have necessary knowledge to support the government's efforts to address the climate change fallout. The proposed project will build capacity of the MFIs on addressing climate change and Real Time Evaluation (RTE) system for measuring effectiveness and efficiency of their interventions using indicators to be identified by this project (see Section 7.2.2). The organisations will integrate RTE system in their core development programmes to make their activities more effective and resilient to climate stress, particularly drought.

In addition, formation and role play of CCAG had provided very good results in terms of enhanced participation of vulnerable communities, women's empowerment, increasing awareness, and identifying vulnerable households and needs-based solutions, etc. The proposed project will use this experience for increasing participation, ownership, women's empowerment, and transfer of technologies and knowledge in addressing climate change in drought-vulnerable areas of the country.

6.2.2 Livelihood adaptation to climate change project (LACC)

The Livelihood Adaptation to Climate Change or LACC project is a sub-component of the bigger Comprehensive Disaster Risk Management Programme (CDMP), which is being funded by United Nations Development Fund, UK Department for International Development, and the European Commission. LACC is being implemented by the Department of Agricultural Extension (DAE) of the Ministry of Agriculture (MoA) of Bangladesh, with technical support from the Food and Agriculture Organization (FAO) of the United Nations.

The first phase of LACC (LACC I) was implemented in 2005-2007. It focused on translating climate change impacts into local and regional agriculture impacts and response options and livelihood adaptation practices. It covered four pilot drought-prone *upazilas* (sub-district) in North-western part of Bangladesh. The first phase was able to accomplish: a) an appropriate institutional framework through the establishment of Technical Implementing Working Groups (TIWGs); b) capacity building to the National Technical Implementation Working Group (NTIWG) and DAE officials on various climate change related topics; c) implement more than 300 demonstrations and field testing out of which more suitable and user-friendly options have been identified; and d) identify 26 adaptation options from farmers and other stakeholders.

The second phase or LACC II was implemented in 2008–2009. It was expanded to the South-western coastal region of Bangladesh, which is characterised by high salinity, siltation, water logging, degradation, freshwater scarcity, cyclones, and storm surges and flooding. Such phenomena have led to substantial loss to agriculture and associated livelihoods. To address these, LACC II worked on identifying and pilot testing livelihood adaptation options that are suitable to local conditions, sustainable and eco-friendly, economically viable, socio-culturally acceptable and integrated with development. With strong stakeholder engagement, the LACC II project adopts an approach which systematically goes through the process of assessing current vulnerability, risks, and local livelihoods; assessing future climate risks; promoting institutional and technical capacities for adaptation; identifying, validating and testing suitable adaptation options; designing location-specific adaptation strategies; and scaling up and mainstreaming. Built into these above are cross-cutting actions, namely: community participation, gender perspective, training, cross-sectoral coordination and policy advocacy. These are further complemented by extension strategies such as farmers exchange visits, meeting with research institutes, backstopping mission, establishment of demonstrations, group meetings, and national level meetings. Some of the beneficial adaptation options identified during this phase are the mini-pond, jujube gardening, improved stove, homestead garden, mini-nursery, etc. The mini pond was an innovative option, but it did not sustain due to unpredictable rainfall. The training manual under the project could be useful for the proposed project. The proposed project assessed present and future climate change impacts, incorporated a number of activities and management tools, i.e., capacity building of communities and institutions on climate change issues, formation of community groups, etc. that were carried out in the LACC projects.

6.2.3 Sustainable Environnent Management Programme (SEMP)

Sustainable Environment Management Programme (SEMP) is the largest UNDP programme in Bangladesh and the first follow-up activity in the implementation of the National Environment Management Action Plan (NEMAP). The project period was October 1998 and December 2006. Executed by the Ministry of Environment and Forest (MoEF), SEMP was implemented by 21 Sub-Implementing Agencies (SIAs) through a UNDP US$26 million grant.

As an important component of SEMP, a programme on ecosystem management in the Barind Tract was designed to improve its dry and degraded ecosystem through community-based sustainable environmental activities. The Environment Management Action Plan for the Barind Area was designed to combat desertification and support environmental awareness, social mobilisation and motivation activities. Three districts of Rajshahi, Naogaon and Chapainawabganj, comprising 25 *upazilas* (sub-district) of the Barind Tract, are covered under the programme. However, the activities are concentrated in the high Barind Tract.

6.2.4 NGO activities in the selected districts

A significant number of NGOs are working in selected districts. It includes but is not limited to CARITAS, BRAC, ASA, CARE, PROSHIKA, Ujjiban, Ashrai, BSO, BDO, Dabi Manabik Unnayan Sangstha, Mousumi, Gana Unnayan Kendra, Padakkhep, VERC, Resource Integration Centre (RIC), Gram Unnayan Karma (GUK), Shotoful, Proyash, and more. These organisations are operating credit programme as well as various rights-based development and awareness programmes. None of the NGOs are implementing climate change adaptation projects although a few of them are doing awareness on climate change. The following table provides a list of projects that are currently being implemented by some NGOs.

Table 3: NGO-implemented projects in the proposed districts

Sl. No	Project Title	Objective and Activity	Donor Name	Implementing organisation
1	CLIMATE	Human rights, capacity building on climate change issues, awareness raising, etc.	Action Aid Bangladesh	BSO, BDO
2	WASH, HEALTH, LAW	Sanitation, health, human rights	BRAC	BRAC
3	Livelihood development project	Improved livelihood of the poor people. Major activities are cow rearing and goat rearing	Bangladesh NGO Foundation	-
4	Vulnerable Group Development Programme	Provide training and food support to the ultra-poor people	Ministry of Women and Children Affairs	Ashrai
5	Improved sanitation programme	Construction of hygiene latrines	Bangladesh Bank	-
6	Education programme	Primary education	ASA	ASA
7	Human Rights and Law Support (HRLS)	Legal support to destitute mother and people.	Jointly by BRAC, AusAid and the World Bank	BRAC
8	Community Empowerment Programme	Increase awareness on development rights of the poor people	Jointly by BRAC, AusAid and the World Bank	-
9	Promotion of renewable energy in rural areas	Promote biogas and improved cook stove	Infrastructure Development Company Limited (IDCOL)	Arbid
10	Resilient project	Asset transfer, income generating activities and social development	NETZ Bangladesh and BOMZ	-
11	Promotion of improved cook stove	Distribute improved cook stove	Infrastructure Development Company Limited (IDCOL)	-

As shown in the table, most of the projects address normal development needs of the community. Though there are some projects related to climate change, the activities seem conventional. This is mainly due to lack of specialised institutions at grassroots level for addressing climate change. The proposed project will fill this gap by developing systems for addressing climate change and building capacity of the institutions and communities.

The NGOs, particularly the Partner Organisations of PKSF, are capable organisations at the grassroots level. They make a significant contribution to reducing poverty through appropriate financial services, awareness raising, capacity building, protection of rights of the poor and vulnerable communities. They have a long-term relationship with the community and the PKSF. Although climate change is a relatively new issue for the civil society community, our partner organisations have begun to address adaptation issues by providing input support for climate resilient agriculture such as developing tolerant varieties, improved cook stoves, vermi-compost and resilient shelter, etc. However, their capacity remains low in knowledge and understanding of adaptation technologies.

7 Selection of Interventions

7.1 Selection of intervention options

7.1.1 Lessons learnt from past and ongoing efforts

The proposed interventions within this project were designed based on the learning of the earlier Community Climate Change Project (CCCP). Within that project, water technologies, i.e., ponds, tube-wells, etc. provided water for drinking and other purposes and vulnerable communities are benefited and most of the activities are still under operation as evidenced by field observations.

In drought-prone areas, submersible tube-wells were installed so that the participants had access to safe drinking water round the year, which was not the case in the past. They have increased access to water for livestock and other household usages. Samples from all tube-wells were found to be free from arsenic. It was documented from the field that time spent, and distance walked for collecting water reduced significantly. It was also informed that incidence of water borne diseases was reduced significantly. A significant proportion of beneficiary farmers diversified their crops in their fields when trained in practicing a drought-resilient cropping pattern under the project. The Climate Change Adaptation Groups (CCAGs) that were formed under the project played an important role in the successful implementation of the interventions, especially through community discussions and peer-to-peer learning.

The design of the project activities took into consideration capacities and experiences of BMDA in delivering technical aspects of pilot adaptation modalities. The proposed project put emphasis on integrated water resource management system to ensure sustainable water use in addressing drought in the drought vulnerable districts of the country. The LACC project also provided guidance in designing activities of the proposed project. Likewise the LACC project, this project analysed present and future climate change particularly for drought vulnerable areas. The project did not consider some innovative options of LACC like mini ponds because it was not effective as evidenced by BCAS in the year 2010 (BCAS, 2010).

The main drawback of the earlier project was that there was no system of understanding whether the adaptation activities were effective in the context of present and future climate change. Though CCCP tried to incorporate Results-Based Monitoring (RBM) system, it had limitations regarding appropriate indicators for assessing the effectiveness of adaptation measures towards increasing resilience of the vulnerable communities. Except for LACC and CCCP, the other projects did not consider climate change at all.

Adaptation assessment is the practice of identifying options to adapt to climate change and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency, social acceptance and feasibility. This pre-feasibility study has considered adaptation strategies and options based on past experience and lessons learned. At the same time, the study reviewed other options carried out by different studies and recommended in various policy documents. The strategies and options have been suggested for drought to cope with and adapt effectively to the changing situation and thus reduce risks and vulnerability.

7.1.2 Current coping/adaptation measures at the community level and future needs

The PKSF team carried out public consultations with the drought vulnerable communities in the project area (as reported in Annex 25). During the consultations, the PKSF Team identified existing coping/adaptation measures as well as future needs of the community. Table 4 summarises the meeting outcomes:

Table 4: Current coping practices and future needs to deal with the impacts of drought by sectors

Sector(s)	Impacts of drought on different sectors	Present coping mechanisms	Future coping measures and strategy	Potential risk
Agricultural Production & Food Security	• Reduces soil moisture and create difficulty in cultivation of land on time • Large areas of land remain fallow • Reduces fertility of agricultural land	Arrange irrigation by DTWs (only if irrigable land is located within the command area of the DTWs)	Install more deep tube-wells, Ensure regular power supply	• Depletion of ground water will be accelerated.
Crop agronomy, vegetable gardening and fruit orchards (diversify-cation of cropping and diet)	• Reduced germination of seeds • Damage to seedlings • Reduced production of *Aus* paddy, *rabi* crops like wheat, maize, potato, brinjal/eggplant, mustard, onion, garlic, arum, and other vegetables. • More plant pests and diseases	Supply water from deep tube-wells, ponds, canals and rivers for irrigation in *boro* fields through Low-Lift Pumps (LLPs). Cover land with thatched roof and cultivate pointed gourd under it that protects moisture and against weeds. Cultivate early variety of *Aman* paddy/ Obtain loans to buy paddy seedlings.	Continue use of LLP throughout the year. Excavation, re-excavation of rivers, canals, *beels*, ponds, etc. to ensure surface water for irrigation. Cultivate short duration/less water required varieties (drought-tolerant) Distribute seedlings by Govt. department if seed beds are damaged.	• Ponds may be filled up with run-off eroded sediments. • High temperature may occur rapid evaporation of pond water. • Farmer may not accept suggested cropping pattern
Aquaculture	Drying up and reducing water of ponds, damaging fish habitat and hampering production severely.	Water supplied to ponds by deep tube-wells.		
Poultry	Affects poultry birds, increasing mortality rate, and reducing production of eggs	Electric fans and water spray used for cooling in poultry farms. Drink boiled pond water	Install deep tube-wells	Rapid depletion of ground water

Health	Scarcity of drinking water Increased dysentery, diarrhoea, skin disease	Tube-well and dug-well for drinking water and sanitation	Install submergible tube-wells with solar powered Re-excavate ponds	Ground water depletion

Participatory research was conducted by Bangladesh Centre for Advanced Studies (BCAS) in 2010. The study identified a number of adaptation activities which include (i) Installation of deep tube-wells and/or use of sufficient number of Shallow Tube-Wells (STW)[19]in crop fields; (ii) Re-excavate ponds/canals/*kharies* for water conservation and use solar PV pump for efficient use of irrigation; (iii) Introduce drought resistant varieties of crops and promote mulching techniques for crop and vegetable cultivation; (iv) Integrated Pest Management; (v) Short duration fish culture; (vi) Raise awareness and build capacities of the farmers; (vii) Cultivate fodder; (viii) Establish treatment and vaccination facilities for livestock and poultry birds; (ix) Increase drought resistant tree plantation; (x) Generate or promote alternative income generating activities (IGA) for lessening vulnerabilities to livelihoods of the wage labourers, women, and marginal groups through cottage industries and making of handicrafts; (xi) Promote best practices in saving cash and food by the vulnerable communities during crisis periods; and (xii) motivate and assist community to preserve foods, water, and fuels.

A study carried out by the Comprehensive Disaster Management Programme II (CDMP II) in 2014 has identified farm level, system level and planning level adaptation measures for future intervention. These are as follows:

Table 5: Adaptation measures at different levels identified by CDMP

Farm level	**System level**	**Planning level**
• Adoption of heat, shock and drought resistant varieties of crops • Probable change from *Boro* rice to wheat/maize or other less water-demanding crops • Mulching • Topsoil tillage • Modification of crop calendars, i.e., timing and location of cropping activities following water stress (keeping attention to livelihood option)	• Modification of irrigation technique – timing, amount and technology (shifting to drip irrigation) • Optimum use of surface, rain and ground water • Adopting techniques for holding soil moisture (for example, crop residue retention) • Optimum use of rain, surface and groundwater • Surface water retention by digging pond • Application of local organic matter • Water retention in crop field	• Government support to farmers if any major crop failure happens. For example, price subsidies, food for work programme, credit, etc. at least to next crop harvest. • Government may provide support in exceptional drought years. For example, 5, 10 or more year return period. • Land type selection and crop zoning • Organised seed production and supply system • Empowering local government or any local body to allocate water in zones of scarcity

[19] According to definition provided by DPHE, the suction head of the tube-well is placed 50 feet (approximately 16 metres) below surface is considered as shallow tube-well (STW).

The limitation of the CDMP II study was that it addressed only the crop agriculture sector. The other sectors, particularly, drinking water and health were not addressed in this study.

7.1.3 Justification for Selected Activities and Delivery Modalities

The concerns around present day drought and future implications of climate change-induced drought for Barind area and its inhabitants are explained with facts and figures in sections 2 and 3, while the activities undertaken to address such issues, although in a disjointed manner, are summarized in sections 6. Based on these facts, the following summary table is constructed to provide a bird's eye view of justifications for selected activities against each problem being identified and various delivery modalities to effectively implement such activities under the proposed project.

Table 6: Climate change induced problems regarding drought and justification of proposed activities

Problem identified	Actions proposed	Justification for undertaking the action	Proposed processes	Comments & Reference (if such actions are already tested)
Drought-induced reduced rainfall causes surface water reservoirs & running streams to dry up (thereby their storage capacities are reduced) Elaborated in section(s):	Improve storage capacity of selected surface water reservoirs & running streams (*khals*/*kharis*) by digging	Digging or taking away earth from choked/filled in ponds and streams will increase depth and enhance capacity to harvest and store increased volumes of water	Manual digging with spades and baskets. GOB's food-for-works programme (FFW) under social protection for the underprivileged provides employment, while maintain rural infrastructure	Highly successful FFW programme towards poverty reduction and maintenance of rural infrastructure.
CC-induced drought causes increased GW abstraction, thereby forces further lowering of GWT much beyond aquifer recharge Elaborated in section(s):	Improve aquifer conditions by facilitating recharge	Install "Managed Aquifer Recharge (MAR)" at (i) roof-top of buildings (i.e, roofs as catchment for rainwater harvesting) and (ii) within ponds	Bringing in technical fix to the problem, forcing human-induced recharge of GWT (since natural recharge capacities have been exhausted)	Piloting in the NWR, especially in Barind provided for promising results. Depleted GWT exhibited gradual upward movement, scientifically proven & managed. Hossain et al., 2019, Hossain et al., 2021
Present day cropping patterns (CPs) are highly water-	Promotion of drought adaptive low-water requiring/	Boro paddy consumes excess amounts of GW for	Partner NGOs will convince farmers and provide them	BMDA, along with DAE of MOA and NGOs have

inefficient & will become increasingly inefficient under CC scenarios Elaborated in section(s):	consuming crops and cropping patterns	sustenance. If Boro is replaced by low water requiring crops/varieties, dry season GW abstraction will be reduced due to lowering of irrigation demand	information, technical support (involving extension service) & inputs, even micro-credit to try out new water-efficient CPs involving crops preferred by market demand	tested crops with low irrigation demand (i.e, Maize, Wheat, mungbeans, etc.). Farm profitability involving new CP appears much higher with a co-benefit of reduction of irrigation demand Reza et al., 2020; Islam et al., 2019.
The viability of fruit trees is reduced significantly with lesser availability of water and subsequent decline in GWT much below root zone of such orchard trees Elaborated in section(s):	Promote Adaptive fruit orchard cultivation	The selection of fruit species which are less vulnerable to declining water table, however thrive well under drought and provide good farm gate price	Partner NGOs will convince farmers and provide them information, technical support (involving extension service) & inputs, even micro-credit to try out new water-efficient fruit trees	BMDA, along with DAE of MOA and NGOs have tested the concept and the farmers' level response is promising. [The region is known for mango orchards, done autonomously] Reza et al., 2020; Islam et al., 2019.
The regional institutions lack understanding on CC, monitoring is weak Elaborated in section(s):	Enhance capacity of government institutions for IWRM/ water saving	Due to lack of understanding and monitoring capacity, such state-run agencies cannot enforce measures towards IWRM	1. Establish CC Unit at BMDA 2. Establish a MAR centre	The needs for such units within government agencies have been highlighted in the consultative processes.
	Enhance capacity of service providers & intermediaries	Due to lack of knowledge and technical capacity, adaptation towards IWRM and climate resilient agriculture is poorly approached/ implemented	1. Knowledge-level improved 2. Real time evaluation of CC response studied 3. Develop intervention database 4. Training of NGO 5. Training of project management 6. Sharing info & outreach	The needs for building capacity will enhance service delivery within the governance system of an LDC.
Communities and farmers are unaware of CC-induced issues,	Enhance capacities and knowledge level of community people including farmers, promote	Without enhancing community-level knowledge and without building confidence among	1. Beneficiary groups formed & made aware 2. Socio-economic profiles are developed	This is a chronic problem felt everywhere throughout the LDCs

reluctant to implement CRA Elaborated in section(s):	peer-to-peer learning	community people, long-term sustenance of adaptation measures will be lost	3. Group meeting for peer-to-peer learning 4. Trainings 5. Exchange visits	

7.2 Description of the selected activities

7.2.1 Capacity building of institutions and communities

Climate change is a comparatively new challenge for the people of Bangladesh. The government sector, NGOs and communities are well aware of disaster management because of their long experience of living with various disasters. But they have very limited experience and knowledge on addressing the impacts of climate change on their lives and livelihoods. The project will establish a Climate Change Unit within BMDA office with its existing staffs, provide them training and support logistics to enhance its capacity in addressing climate change. It will also provide support to the government to establish MAR centre and provide them training. They will involve in implementation of MAR models under this project. The project will also provide training to NGOs and community people on climate change issues so that they are able to address the problems in their lives and livelihoods. As stated earlier, promoting adaptation at the community level requires specialised institutions on climate change. The training is designed to fulfil these needs. The organisations will learn about climate change and how to address the impacts and hence will incorporate the Real Time Evaluation (RTE) system into their core programmes. PKSF will monitor the organisations so that they are focused on the issues of climate change.

The RTE results (see below) will be shared with these organisations through seminars, workshops and other publications. Then the trained organisations will nominate a focal person on climate change issues within the core staff who will look after the climate change issues in the organisations.

We expect that the organisations will use the lessons from RTE and use the process to measure effectiveness of their own interventions. Hence, the selected activities under the project are:

- Capacity building of institutions and communities
- Re-excavation of ponds
- Re-excavation of canals
- Installation of MAR system[20]
- Drought resilient cropping pattern.

[20] Two types of MAR system have been contemplated here. (1) Harvesting rainwater in micro-catchments (such as roof top of buildings) and subsequent MAR; (2) harvesting of rainwater in traditional but re-excavated ponds and subsequent MAR.

7.2.2 Capacity of the NGOs

The selected Partner Organisations (POs) of PKSF are the Implementing Entities of the project. POs have long-term experience in various development activities including livelihood development, awareness on social issues like child marriage, and disaster management issues. These organisations provide a wide range of development services including financial, health, educational, capacity development, technology transfer and business development services to disadvantaged segments of the society. Mobilisation of poor people and provision of necessary training with appropriate financial supports have been the initial and continuous interventions of POs. Currently, PKSF has 278 partner organisations throughout the country.

It is to be noted that PKSF has set criteria for periodic evaluation of the performance of its partner organisations. The criteria include financial efficiency, economic efficiency, operational efficiency, growth indicators, financial strength & risk management, accounting & internal control system, social performance, human capacity and governance. Each of the criteria has several indicators to assess performance of the POs. Based on the performance criteria, the organisations area categorised as extra-ordinary, excellent, good, average, sub-standard and requires special attention (RSA). The project will select the implementing entities among the first three categories of organisations (extra-ordinary, excellent, good). The selected partner organisations will recruit project staffs for implementing activities at the field level. PKSF will develop project implementation manual and guidelines for the partner organisations as well as for PMU. The newly recruited staffs will receive training on the manuals and guidelines. PKSF will ensure completion of Anti-Money Laundering/Countering Financing of Terrorism (AML/CFT) due diligence with satisfactory results in the selection process for IEs and Service Providers.

7.2.3 Real Time Impact Evaluation (RTE) and its methods

As described above, several projects have been implemented to address climate change but there are significant knowledge gaps in terms of project preparation, implementation and evaluation. There is no example of measuring real time impacts of adaptation interventions in the country. This project will introduce the RTE system in order to measure real time impacts of the proposed interventions. Hence, the project design team proposed draft indicators for measuring effectiveness of the proposed interventions (Table 7). These indicators will be finalised during the baseline study under the RTE system. The project will generate knowledge on resilience against drought and share the lessons with various levels of stakeholders including government and non-government organisations and development partners.

The project will design and carry out RTE study to assess the effectiveness and efficiency of the proposed interventions. The study will design a baseline questionnaire based on the project's Theory of Change focusing on possible indicators for measuring resilience against climate change induced drought. This study will establish a baseline on communities' resilience against drought as well as identify indicators for measuring effectiveness of the interventions. Then another set of questionnaires and checklists will be developed based on the identified drought resilient indicators. Periodic studies will be carried out for evaluating the interventions. The knowledge and lessons to be captured through these studies will be shared with all levels of stakeholders. The selected NGOs will be trained to carry out this exercise to assess their interventions in the context of climate change induced drought. Hence, they will adopt the system to secure their loan investment by reducing drought impacts on their interventions.

Table 7: Suggested Indicators for Impact Measurement

Impact Indicators	How to measure
Awareness increase	Number of people with increased awareness of climate change issues, level of awareness of climate change issues, role of women in household's decision-making, etc.
Recovery from weather shocks	Alternative sources of income to regain income levels to pre-shock conditions
Impact of weather shocks on household assets, income, expenditure, disease	Asset loss/income/expenses/disease episodes
Access to water before, during, and after drought (for drinking, agriculture, household)	Amount of water and proximity to water source
Food Security	Nutrition index (calorific intake) /Food insecurity experience scale/Household food diversity index

Detailed methodology of RTE is presented below:

*Baseline study***:** The purpose of this baseline study is to identify the drought resilient indicators as well as the benchmarks against each of the targeted indicators. This study intends to identify the baseline reference points to establish the present existing scenario of the beneficiary households in light of all the indicators. Sample size will be determined using appropriate sampling techniques. The data will be collected through quantitative survey. The required tools and techniques will be developed based on analysing the secondary information collected at the initial stage of the project. A detailed questionnaire addressing all climate vulnerability and socio-economic conditions of the targeted community will be developed for this study supported by guidelines and code sheets to collect quantitative data from the selected field. The pre-testing will also be carried out for this study. All types of valid feedback will be considered to develop appropriate and user-friendly sets of questionnaires.

A training session will be organised for designated staff of IE and enumerators to collect data from field. They will be guided with proper instruction and possible solutions to the problems they faced.

The quantitative data will be entered through MS Excel/SPSS and the data will be processed and analysed through SPSS software. The selected variables will be chosen on the basis of indicators required following results framework. All the data will be critically assessed during and after the collection process to ensure the quality of data. Finally, a baseline report will be produced.

*Outcome level on RTE system***:** At the outcome level, an Outcome Assessment Sheet (OAS) will be developed based on the indicators to be developed under the project. The OAS will be filled up by carrying out interviews with the project participants. It will help assess the intermediary results towards achieving "resilience of a community to the impacts of climate change". Resilience will be measured at five scales, i.e., non-resilient, slightly resilient, moderately resilient, highly resilient and completely resilient.

Questionnaire survey for impact assessment:

The study will be conducted following a quasi-experimental design. The quantitative data will be collected through household survey using specific sets of questionnaires with regard to the project objectives and indicators that will be developed.

Qualitative assessment:

The study used structured questionnaires as a quantitative tool for collecting data. An Outcome Assessment Sheet – OAS and an Impact Assessment Sheet – IAS will be developed to carry out qualitative assessment of each activity. Heads of households or their spouses were selected for this purpose.

7.2.4 Options for surface water supply and groundwater recharge

Based on current statistics, individual water requirement is 62.43l/day. This project intends to target about 215,000 people, who currently have limited access to clean water. The project, therefore, needs to provide 4,899,194 m^3 of clean water per year for the targeted beneficiaries. Given the quality requirements of household water, this water will be sourced from ponds, canals, and MAR models under this project.

In addition, this project intends to provide water for irrigation. Assuming that summer crops are rain-fed, winter requirements for 15,000 farmers (or approximately 4,950 acres) under current agricultural practices would be 23,675,850m^3(per acre 4,783 m^3). The project intends to reduce demand by 70% during winter, therefore 7,102,755 m^3 of irrigation water will be required for the targeted 15,000 farmers. Given the low requirements of irrigation water, this water will be sourced from surface water supplies.

The project will address the water problem in Naogaon, Rajshahi and Chapainawabganj districts through '**4R**' principles [i.e., **R-Recharge** (Groundwater will be directly injected through recharge well, dug-well or shaft using rainwater harvesting technique); **R-Reuse** (It will help to utilise/reuse rainwater/run-off water through recharging groundwater by MAR model); **R-Restore** (It will help to protect the depleting groundwater resource through water banking system as well as any sorts of quality hazard); and **R-Recycle** (Recycling process of surface water and groundwater system creating an ecological balance). Therefore, to balance usage and ensure that no harm is done to the groundwater supplies, this project must be able to provide all drinking and household demand, which will come from ground water supplies, as opposed to irrigation demand which will come from surface water capacity.

The table below reports a comparison of main alternative options to increase water supply.

Table 8: Comparative analysis of various interventions in water sector of Barind region

Name of the measure	Technical feasibility	Economic/financial viability	Social acceptance	Gender aspects	Other social and economic vulnerabilities
Canal re-excavation	It is a simple technology. Usually, canal is excavated throughout the country for drainage and irrigation purposes. In the Barind region, there is a huge number of natural canals which are locally called *Khari*. The project will re-excavate them for preserving rainwater for irrigation.	The project will enhance capacity of local institutions (BMDA and NGOs) as well as communities on maintenance and management of the canals. Community mechanism will be developed and water pricing will be introduced in collaboration with BMDA and CCAG to raise funds for post project operation and maintenance. An initial investment cost for preserving 1 m^3metre of rainwater in the canal is very low (US$0.14) considering that the canals will be providing service for at least 10 years without any major maintenance (i.e., re-excavation or de-siltation).	Canal water for irrigation is well accepted by the people of the region and the country. Use of canal water is a common practice.	Canals will be used by all the people of the region. Women will be especially benefitted because they can easily collect water for household uses like bathing, washing, etc., thus avoiding walking over long distance to fetch water. In addition, the use of water canal reduces drudgery caused by the use of hand tube-wells, which are very hard to pump.	The re-excavation of canals will increase access to irrigation water, thus increasing yields and potentially reducing crop losses.
Pond re-excavation	Pond re-excavation is a simple technology of preserving rainwater to be used during the dry season. It requires labour, spades and baskets along with an excavator. Pond re-excavation is a traditional measure throughout the country. In Barind region, there is a great number of government owned large ponds (called *khas*). Some of the *khas* ponds are re-excavated by the BMDA in the traditional form. Considering present and future climate change impacts in this region,	Water pricing will be introduced for collecting funds for future maintenance of the ponds. An initial investment cost for preserving $1m^3$ of rainwater in the pond is very low (US$0.19) considering that the ponds will provide services for at least 10 years without major operation and maintenance costs. Like canal, maintenance costs are very low.	Pond water is widely used by communities for irrigation and household domestic purposes. So, it is already well accepted.	Gender benefit is similar to canal water.	As for canal re-excavation,ponds will also provide irrigation water.

Name of the measure	**Technical feasibility**	**Economic/financial viability**	**Social acceptance**	**Gender aspects**	**Other social and economic vulnerabilities**
	this project will design the pond in such a way that it can capture maximum amount of rainwater and run-off. The project will also plant trees around the ponds to shadow the water surface, thus reducing evaporation. Ponds will be managed by community groups. Pond and canal will be complementary. In areas where canal is available, the project will re-excavate canals. Ponds will be excavated in those villages where canals are not available.	Local institutions and community members will be trained to ensure proper maintenance of the re-excavated ponds.			
MAR techniques	It is a new and innovative technology in the project area. Installation of the MAR system requires a surface with gradient. The surface may be a roof or a ground. A well is also required to push the water into the aquifer. The project will hire technical experts. Some NGOs have demonstrated the MAR system in Rajshahi and Chapainawabganj district in the Barind region. The project proposed two types of MAR technologies i.e. roof-top based and recharge well in ponds.	It is a comparatively low cost technology. The investment cost of a roof-top MAR is estimated to be US$1,200. This MAR is expected to inject 224 m^3 of rainwater into the aquifer annually. The cost per cubic meter of water is very low (US $0.54) considering that the MAR will be providing services for at least 10 years with limited maintenance costs. The proposed pond based recharge well of MAR technology is also cost- effective (US $0.20 per cubic meter of water). MAR will accelerate ground water recharge, which will in turn increase the availability of ground water for irrigation and drinking.	The use of ground water is well accepted by communities.	There are many hand tube-wells that do not work due to depletion of groundwater. MAR will increase ground water storage. Hand tube-wells are expected to be reactivated as a consequence of the groundwater recharged by MAR (Rahaman, et al 2020) Women will be greatly benefitted having working active tube-wells close to their house.	Recharged aquifers will reduce crop losses and will increase yields. Recharged aquifers will also provide safe drinking water, leading to reduced diseases and related medical costs.

Name of the measure	**Technical feasibility**	**Economic/financial viability**	**Social acceptance**	**Gender aspects**	**Other social and economic vulnerabilities**
		Maintenance of this technology is very simple and does not involve costs. Community people will carry out maintenance interventions. The maintenance activities of MAR is seasonal. Rain water is captured during monsoon (Mostly June to October). After recession of monsoon, the mouth of the well is covered so that any solid or liquid wastes would not enter into it. Secondly, with the start of monsoon, surface of the MAR structure (mainly roof which would be used to capture rain water) is required to clean with sweep. These are very simple maintenance activities that the community people can easily carry out.			
River dredging	It is highly technical. Environmental and Social (ES) category A	Detailed feasibility study requires to assess economic/financial viability. Costs are higher than re-excavation or MAR.	Generally well accepted.		-Limited scope to involve community people in works.
Diversion of river water	It is highly technical, ES category A	Detailed feasibility study required to assess economic/financial viability.	It may give rise to resettlements.		- Limited scope to involve community people in works.
Rain water harvesting at household level and	It is a simple technology but not used in Barind region.	The investment cost of a rainwater harvesting system for a household with 10 m^3 water tank is estimated for about US$1,190.	People of Barind region are not used to water harvesting (in	If it is financially and socially viable, women would get benefitted	-

Name of the measure	Technical feasibility	Economic/financial viability	Social acceptance	Gender aspects	Other social and economic vulnerabilities
public buildings	Rainfall water amounts are highly seasonal, thus limiting the potential use of water harvesting.		water tanks or jar) and do not drink rainwater.	mostly having water at their house.	
Dug-wells	It is a simple and innovative technology. The BMDA is implementing this activity. But it may contribute to over-exploitation of ground water.	Dug-wells are a financially viable technology if they are installed at the right site (the aquifer is not uniform throughout the Barind region).	It is socially accepted.	Women will be greatly benefitted because they have access to water close to their houses.	As for other techniques, access to ground water increases incomes when water is used for production purposes.
Deep tube-wells	It requires specialised knowledge and equipment both for initial investments and maintenance. The BMDA massively installed deep tube-wells. It has severe consequence on the conservation of ground water. resources.	It is financially viable because farmers buy water from deep tube-wells for irrigation.	It is socially well accepted.	Women do not get direct benefit from it because it is installed in crop fields, which are distant from home.	As above
Submergible tube-wells	It is a simple technology. The Department of Public Health and Engineering (DPHE) suggests and implements this technology for ensuring drinking water in the Barind region. Rich people also install submergible tube-wells with their own resources. It may have severe consequences on the conservation of ground water resources.	It is economically and financially viable because it is low cost and durable technology.	It is socially well accepted.	Women are highly benefitted because they can fetch water from a source close to their houses.	

Based on the above analysis, the project proposes re-excavation of ponds, re-excavation of canals and Managed Aquifer Recharge system as adaptation measures to climate change in water sector for drought vulnerable areas of the country. The proposed interventions will ensure sustainable water management as well as improve adaptive capacity of the drought vulnerable community in the selected districts. It is to be noted that multiple water management options are proposed under this project. The purpose of pond and canal is similar but complementary to each other. There are some areas where there is no canal. So, ponds will be re-excavated in these areas. The purpose of MAR is different. MAR is chosen for regeneration of ground water system in Barind region. Presently, it is the only technology in the country to re-generate ground water system in the Barind region. Both dug-wells and tube-wells were considered as alternatives to ponds and canals. However, dug-wells and tube-wells have contributed to the over-exploitation of groundwater, which is already under pressure. This is why these wells are not considered for the proposed project. There are some rivers that could be dredged for accumulating surface water. However, this has been excluded since it would not comply with the ESS requirements of SAP projects.

Re-excavate ponds

Barind Multipurpose Development Authority (BMDA) has been working in the drought-prone Barind region since the ’80s. Primarily, the authority puts emphasis on installation of deep tube-wells for irrigation. As the depletion of ground water became more noticeable, the authority re-excavated a number of ponds and canals to manage surface water for irrigation. However, there still is huge demand for water for irrigation and household usage. The project will increase surface water storage by capturing rainwater through re-excavating ponds. The ponds will preserve rainwater which would be used for irrigation and household purposes.

Traditionally, there are lots of ponds in the drought affected Barind region. These ponds preserve rainwater during monsoon for lean periods. Over time, the ponds fill up with soil from erosion of banks and surrounding areas driven by rainwater. Thus, these ponds quickly dry up immediately after monsoon rain due to evaporation and their shallow depths. The project will re-excavate 300 ponds to preserve rainwater for supplementary irrigation and household usage. On average, the size of ponds will be 2000 square metres with a depth of 2 to 2.5 metres. The excavated soil will be used to build the pond’s dyke of about 3 metres width. The project will raise ponds’ dykes to protect soil deposit from surrounding run-off. The project will also plant grass and deep-rooted trees on the slope of the ponds to protect erosion of dykes. In addition, the project will establish a community mechanism for regular maintenance of the ponds. PKSF practiced this type of measures while implementing CCCP in the year 2012-2016. These ponds will support 15,000 small and marginal farmers providing about 1500,000 $m^3$of water for irrigation.

The purpose of the ponds is to preserve rainwater for supplementary irrigation use. In addition, trees will be planted to protect slope erosion as well as to work as shed on the water which will protect evaporation to some extent. In addition, protection from slope erosion will increase plants and bird species. For safety of the children, the pond will be fenced with bamboo sticks.

BMDA also re-excavate ponds. But BMDA leases the ponds to local business people for commercially fish cultivation. Poor people do not have access to these ponds. Besides, there is no sustainability mechanism of these ponds. Hence, these ponds loose depth and require further re-excavation.

The ponds in the Project area (Rajshahi, Chapai-Nawabganj and Naogaon district) were excavated long back and nearly more than 50-75 years ago and sometimes even more. But at present erosion of the top soil (Barind clay) due to severe declining trend of groundwater level has partly or mostly silted ponds and canal, resulting decreasing the runoff water holding capacity. It causes water imbalance condition through poor groundwater recharge mechanism in the area. The re-excavated ponds will increase the holding capacity of runoff water conservation into the transformed (re-excavated) ponds as perennial water bodies. So the pond re-excavation approach for runoff water conservation in the project area will open new venue for not only the more conservation of runoff water but will also help the area for keeping undisturbed water balance through recharging more groundwater. Presently due to lack of proper conservation of runoff water, it is mostly flowing through canal into small and mighty rivers basins in the country. The re-excavation work in ponds will also help to keep ecological balance and conserved bio-diversity in the area as application of nature-based solution (NbS).

Re-excavation of canals

The Barind region has large number of natural canals which are locally called *Khari*. These canals are characterised by narrow and steep slope which lets the rainwater quickly to the nearby river. Hence, the local farmers do not get water for irrigation. Re-excavation and renovation of these canals will increase surface water storage and meet demand of water of the farmers. Given the context as described in above section, this project will re-excavate canals to improve surface water storage for irrigation that will in turn save ground water.

BMDA has also similar type of activity. But BMDA has not introduced sustainability mechanism and there is no post-project monitoring and operation system. As a result, many of the canals lose depth and require further re-excavation.

Implementation of Managed Aquifer Recharge (MAR) models

Implementation of MAR models mainly depends on hydrological and lithological characteristics of a region. The formation of Barind Tract is characterised by the Pleistocene clay deposits (Barind Clay) comprising surface lithology which is hydro-geologically semi-impervious and is composed of clay-silt aquitard [low infiltration rate: 1-2 mm/day (UNDP, 1982) having a thickness of 3.0-47.5 m] of a semi-impervious nature. The aquifer system is single to multiple layered (two-four) of Plio-Pleistocene age (thickness: 5.0-42.5 m) (Jahan et al., 2007) having suitability mostly for drinking and household purposes and scope for irrigation uses is limited (Jahan, 1997).As stated in section 3, the average rainfall of Barind area is very low (44% less than the national average) with much seasonal nature. At the same time, high seasonal and annual rainfall variability (20-26%) creates a great challenge for water management. The Precipitation Concentration Index (PCI) (Oliver, 1980) (average: 19.5) indicates rainfall distribution of irregular to strongly irregular nature with high seasonal variability. Moreover, the mean Seasonality Index ($\overline{SI}$) (Kanellopoulou, 2002) (0.94) also reveals the markedly seasonal rainfall pattern with a prolonged dry period. This irregular rainfall coupled with low permeability of the sub-surface (hydraulic conductivity ranging from 0 to 20 m/day)[21]affects natural ground water recharge. In addition to this hydro-climatic cause, ground water exploitation is also contributing to depleting ground water in the region. To ensure the sustainability of ground water resource management with high rainwater harvesting (RWH) potentiality during the rainy season, the Managed Aquifer Recharge (MAR) model was

[21] Sajal K Adhikary, A.B.M. Irad Hossain, Mukand S Babel and Ashim Das Gupta (2013). DRASTIC-based vulnerability assessment of Barind tract aquifer in northwestern Bangladesh, 4th International Conference on Water & Flood Management (ICWFM-2013).

piloted and widely enacted as the Integrated Water Resource Management (IWRM) strategy in 2014. This MAR model injects rain/run-off through recharge pipes/shaft and dug-well to augment groundwater during the rainy season that can fulfil nearly 70% of groundwater demand under business as usual.

To determine the aquifer properties of the proposed project area, existing aquifer test data of the Bangladesh Water Development Board (BWDB), development test data of the Bangladesh Multipurpose Development Authority (BMDA), aquifer tests conducted in connection with other projects as well as in present study were collected and analyzed. The hydraulic properties of aquifer as estimated Jacob method (1946) (IWM 2006) and the calculated values are given in **Table 20.**

Table 9: Aquifer hydraulic properties as calculated by Jacob method for the project area

No.	Upazilas	Transmissivity (T) m^2/day	Specific Yield Sy
	Rajshahi District		
1.	Bagha	1800	0.10
2.	Bagmara	1800	0.09
3.	Charghat	600	0.08
4.	Godagari	400	0.05
5.	Mohonpur	800	0.05
6.	Paba	600	0.06
7.	Puthia	1000	0.05
8.	Tanore	400	0.05
9.	Durgapur		
	Chapai-Nawabganj District		
10.	Gomostapur	400	0.04
11.	Nachole	400	0.05
12.	Nawabganj	600	0.06
13.	Shibgonj	400	0.15
	Naogaon District		
14.	Atrai	2300	0.15
15.	Badalgachi	1800	0.08
16.	Dhamoirhat	600	0.12
17.	Manda	400	0.05
18.	Mohadevpur	600	0.05
19.	Naogaon	1200	0.08
20.	Niamatpur	600	0.06
21.	Patnitola	600	0.08
22.	Porsha	400	0.05
23.	Raninagar	1500	0.10
24.	Sapahar	400	0.04

From aquifer test results it is observed that the transmissivity (***T***) values in the project area varies from 400-2300 m^2/day and that of specific yield values ranges from 0.05-0.15. But in the Barind Tract T values are comparatively low and ranges from 400-600 m^2/day with exception of 1000 m^2/

day at the side of Barnai River in Tanore (Barind Tract) Upazila. On the other hand, the specific yield (***Sy***) in the Tract is also lower and vary from 0.04-0.06.

The project area has two major distinct physiographic units: high relief Barind Tract and low relief floodplains with varied elevation difference from 9 m to 47 m from the mean sea level in Naogaon and Nachole areas respectively. The Pleistocene Barind clay floors, the Barind Tract area and bordered by broad valley of the river Ganges (Padma). The valley is fringed by narrow floodplains in the western part of the project area. The eastern part of the river-valley gradually widens up and ultimately merges into vast floodplains of the river Ganges (Padma) further to the recent deltaic plains in the south and southeast. There are two floodplains in the area, the young floodplain of the river Ganges (Padma) and older floodplain of the river Mahananda and Atrai.

The alluvium of Holocene (Recent) age are consisting of unconsolidated deposits of active channel, active floodplain and modern deltaic deposits, and is composed of sand, silt and clay. The Pleistocene deposits are termed as the older Alluvium that forms the Tract. It is believed that the raised Tracts are formed due to tectonic upliftment. The geomorphic processes acting in the area are controlled by the subsurface basinal configuration. The distinct units are present in the project area, which are: Barind Terrace/ Barind Tract, and Mohananda Floodplain. The landforms of the project area are mostly level in the eastern area and undulating in the western area. The depressions (*beels*) in the Mahananda floodplains remain watery almost throughout the year due to steady water flow from upland river systems.

There is a significant lithological variation between the Tract and the adjacent young and older floodplains. The raised Tract is formed by thick clay, which is underlain by thick coarser sediments from Early Pleistocene to Late Pliocene. The clay lithology is more compact and dense; the degree of diagenesis is higher with low hydraulic conductivity of 1-2 mm/day (UNDP, 1982). The older sediments form the major aquifer system of the project area. The thickness of clay horizons and measured water levels indicate there is possibly for presence of groundwater pressure-head.

Considering the hydrostratigraphic variability, groundwater flow situation and the spatial distribution of aquifer units, the project area can broadly classified into two different aquifer systems, e.g., Mohananda floodplain aquifer system and Barind Tract aquifer system. Based on geophysical well logging data (Jahan et al., 2007), it is revealed that the top clay-silt layer of the Barind Tract (Rajshahi, Chapai-nawabganj, Naogaon) has a maximum thickness (<45 m) and decreases towards the western part in the Mahananda floodplain (Shibgonj Upazila) with the minimum thickness of > 10 m. The aquifer systems in Barind Tract possess single aquifers with depth ranges from 8.0 to 42.5 m, and mostly the Mahananda floodplain aquifer systems possess double/multiple aquifer system. Naturally, area with lower thickness of top clay-silt layer (mainly Mahananda floodplain area) have higher potentiality for natural groundwater recharge. Piezometric (Figure 20-22) maps of three different seasons i.e. rainy season, winter season and summer season is presented below:

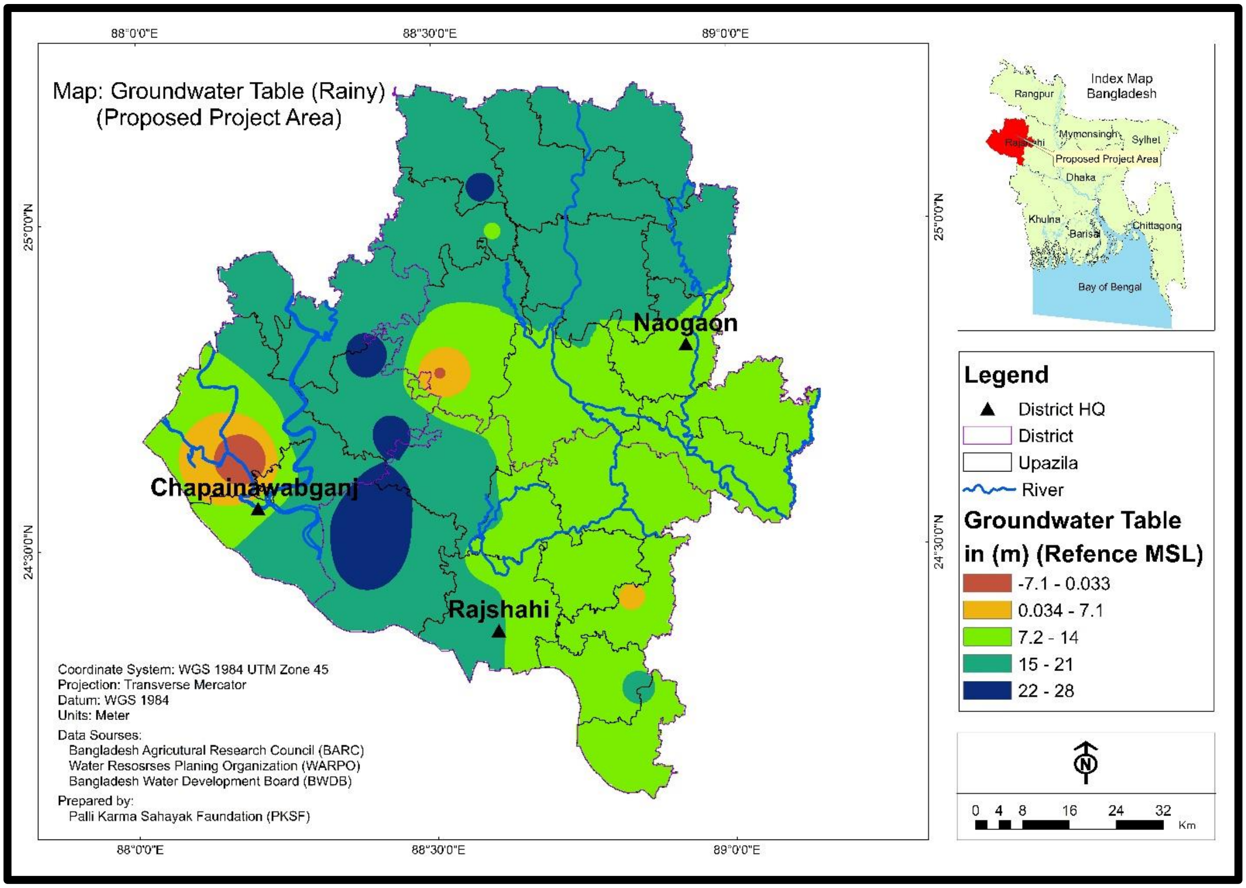

Figure 25: Piezometric map of the proposed project area during rainy season

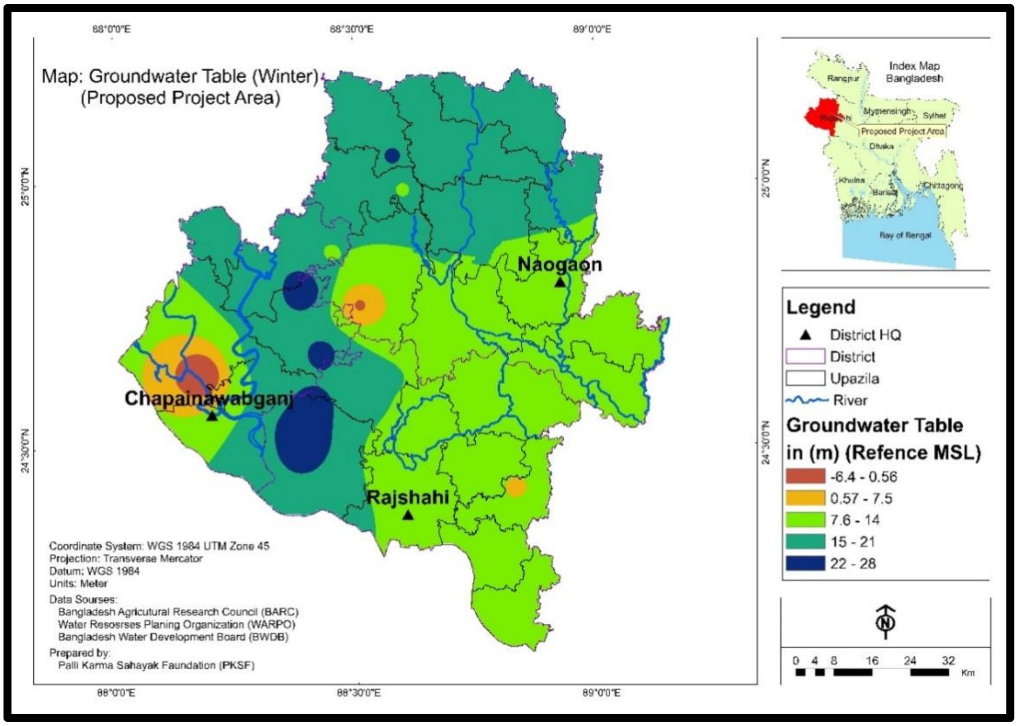

Figure 26: Piezometric map of the proposed project area during winter season

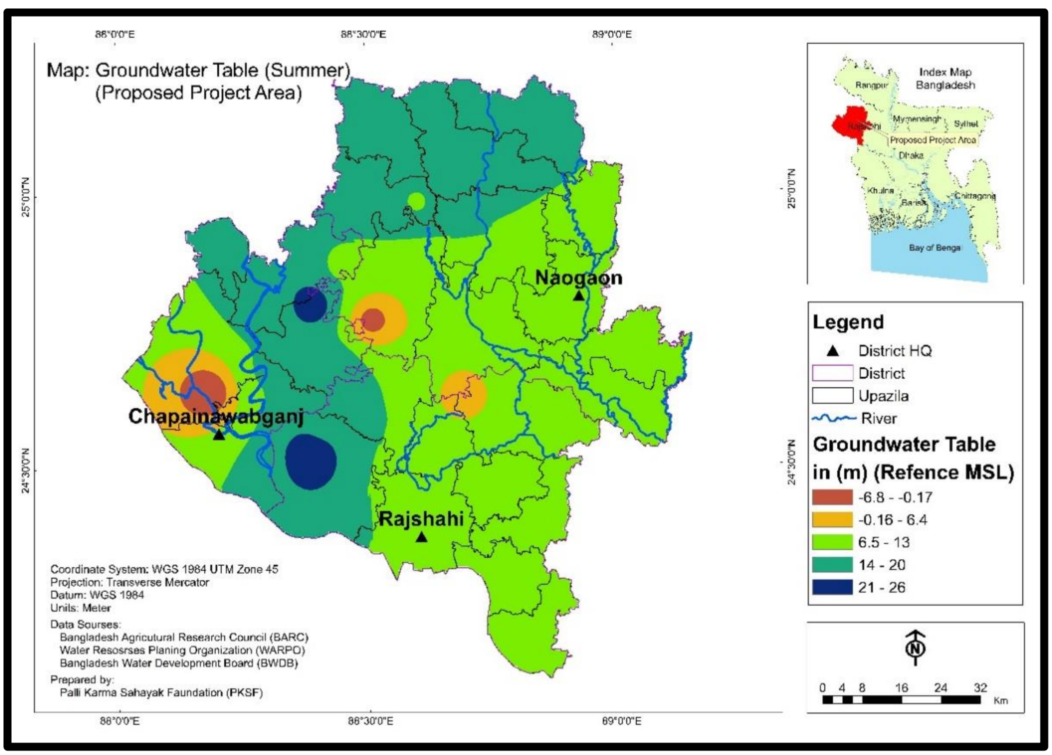

Figure 27: Pizometric map of the proposed project area during summer season

It is observed from the above analysis that the project area is mostly single layered aquifers. Their thickness is also suitable for installation of a recharge well (ideally 10-15 m). So, the project area shows high potential of implementing MAR system using recharge well. The operation of MAR model and its impact to augment groundwater resources was assessed by monitoring the depth of GWT during the period from January 2014 to December 2016 by DASCHO Foundation (a local research and development NGO working in Barind region) in Rajshahi district (Figure 23). The results showed that during the period from February to May in every year since last 2-3 decades, especially in summer season, the GWT was declining, but came back to its original level in the following monsoon period up to 2004 due to sufficient amount of groundwater recharge with respect to withdrawal. From 2004 to 2014, the GWT did not come back to its original level. MAR was first piloted in 2014 in Tanore *upazila* of Rajshahi district. In this year, the GWT declined by 1.31 m in January 2014 and started to raise during monsoon in the same *upazila*. It was found that the GWT raised up to 7.82 m in December 2016 in MAR-pilot areas. This means that GWT raised 6.51 m in three years (2014-2016) due to installation of the MAR

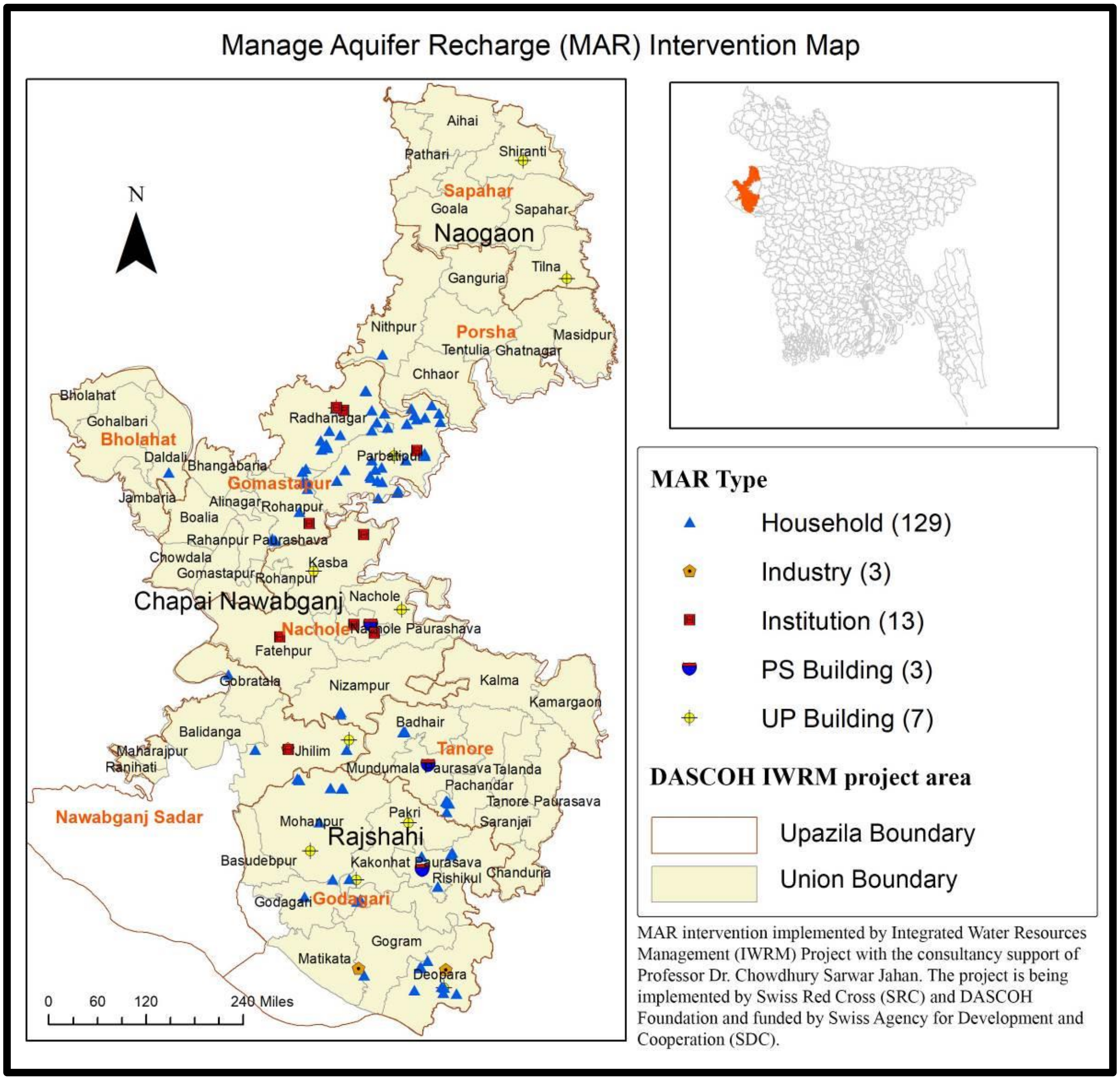

Figure 28: Distribution of MAR system in the Barind region

(Source: Scoping Report on Preparing National Strategy for Managed Aquifer Recharge (MAR) in Bangladesh, Final Report, Commissioned by: 2030 Water Resource Group (WRG 2030), Dhaka, Bangladesh, 2020)

After the implementation of MAR model, level of GWT has started to reverse due to injected or forced rainfall recharge to groundwater artificially.

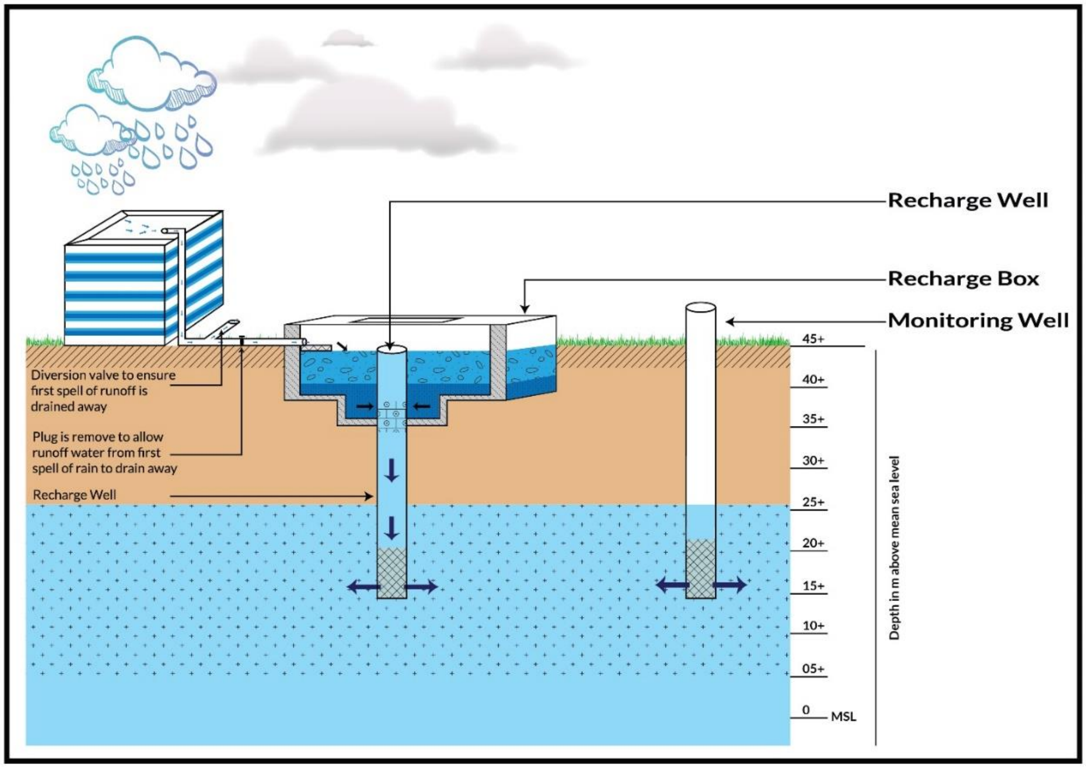

Figure 29: Schematic Diagram of Roof-top based Rainwater based Managed Aquifer Recharge Structure

The project will increase access to clean water for about 60,000 beneficiaries for drinking and household uses through MAR system. These households will require approximately 450,000 m^3 (assuming 62.43 liters/person/day). To increase access to clean water, the project will install 2,500 rooftop-based MAR systems at public and private buildings and 40recharge well in 40ponds of about 2,000 m^{2}each with a depth of 5 meters. Considering an average roof size of 200 m^2, a building can capture 224 m^3 of rainwater annually (annual average rainfall is 1,400 mm and run-off coefficient 0.8). So, 2,500rooftop-based MAR systems will inject approximately 560,000 m^3 of water. In addition, the project will install 40recharge wells in 40ponds. These recharge wells will inject approximately 400,000 m^3 of water. The project will install shallow piezometres to monitor the effectiveness of a MAR system.

It is to be noted that this project suggests different types of water resource options for the drought vulnerable areas. This is primarily due to ensuring sustainability of water management in the drought affected areas. It will ensure present use as well as preserve water for future generation through MAR and rainwater harvesting in ponds and canals.

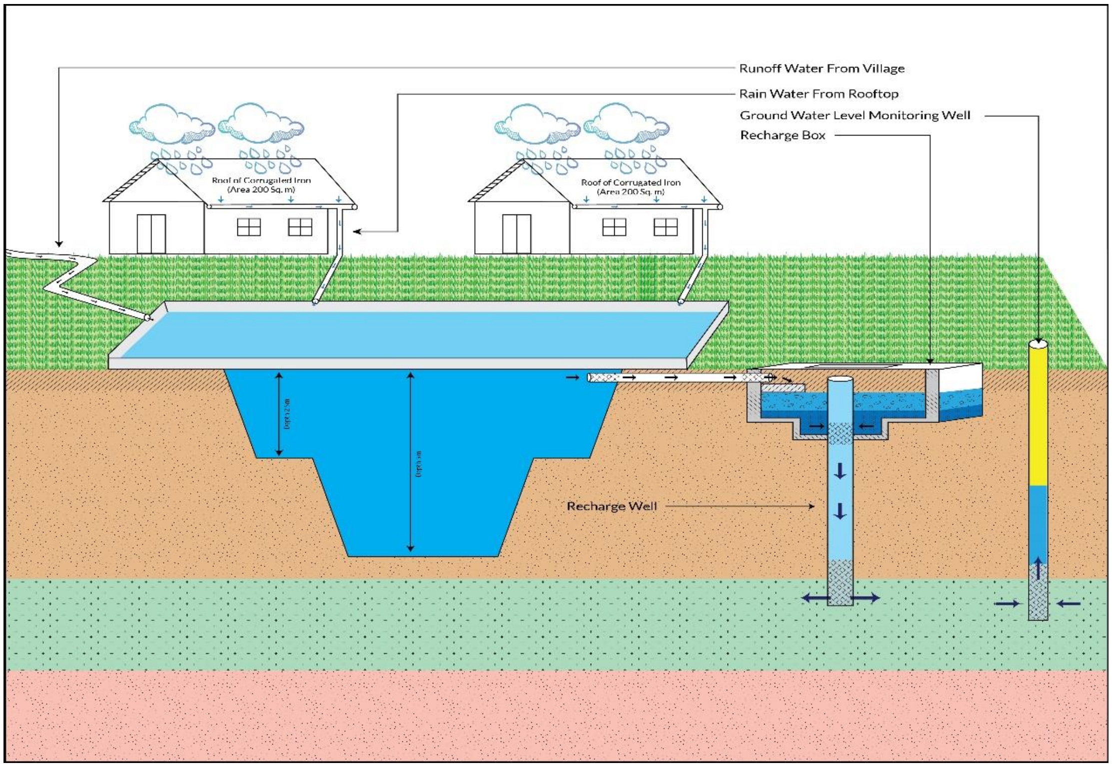

Figure 30: Schematic diagram of pond-based MAR system

7.2.5 Drought resilient cropping pattern, fruits and horticulture

Poor farming communities of the Barind Tract depend on a regular crop production within and between years for household nutrition and livelihoods. However, lack of access to water for traditional crops during droughts is a fundamental and ever-growing barrier.

Rice, a traditional crop, consumes a tremendous amount of water for its production. During the rainy season, there is no constraint on the amount of water available through precipitation. However, during the remaining months (up to 9 months), there are two further cropping seasons, where precipitation is low, highly variable and affected by climate change. With large infrastructure projects, ground water has become easily available to many villages and they continue to grow rice year-round using traditional rice varieties and irrigation. This however is having a significant impact on the GWT (see above). The project, therefore, proposes a paradigm shift in how villages can continue to produce traditional crops that have no effect on the ground water. Water access and aquifer recharge have been discussed above, however in order to minimise demand on the aquifer, this project intends to promote drought resilient cropping methods which need a minimal amount of irrigation.

Providing drought resilient crop varieties combined with knowledge of crop management that include a climate adapted cropping pattern, have successfully improved resilience in terms of food security and livelihoods. Providing access to water alone will not solve the resilience crisis since traditional crops consume a lot of water and groundwater reserves are not sufficient in the long term to satisfy the demand. For these reasons, this project will promote low water consuming and drought resistant crops and varieties to improve food security and livelihoods within target communities of the selected districts. In this way, it is expected that if 15,000 small and marginal farmers apply the project proposed techniques and varieties then about 352,999,525 m^3 of ground water will be saved during the winter season.

The National Agriculture Research Institutes (NARIs) of Bangladesh are continuously doing research and developing various stress tolerant varieties. BRRI *dhan*56 and BRRI *dhan* 57 are the two drought resistant and short duration rice varieties that can live up to 15-20 days without soil moisture. BINA 7 is also short duration rice variety which is termed a drought-escaped variety. These varieties are mainly cultivated in the *Aman* season[22] (rain-fed). The use of mentioned improved rice varieties would enable farmers to resist and escape droughts in the post-monsoon period. The traditional varieties are affected by drought in two ways. First, it delays the seedlings due to early drought caused by delay to the onset of monsoon in the months of June-July. Secondly, these varieties are affected at the grain filling stage during the post monsoon period due to the rapid recession of monsoon. These problems will be solved by replacing the traditional varieties with the proposed selected varieties. In *Boro* season[23], rice is traditionally cultivated with ground water irrigation which has a negative impact on the GWT. Therefore, this project proposes less water consuming crop varieties. *BARI* wheat 26 and *BARI* Mustard 15 are the two crop varieties that require only one or a maximum of two irrigation events in their life cycle. These varieties will be promoted in *Boro* season replacing rice varieties. This will reduce irrigation cost as well as crop damage. In the pre-kharif[24] (*Aus* season), *aus* rice (BRRI 14), jute, sesame, etc. are typically cultivated which are long duration crops and frequently affected by drought. These crops also delay the *Aman* crops. This project will promote the replacement of these crops with *BARI* Mung 6 which is a short duration and less water consuming variety. So, the proposed drought-adaptive cropping pattern stands as *BRRI* 56&57/*BINA* dhan 7- *BARI* Wheat 26/*BARI* Mustard 15- *BARI* Mung 6. In addition to this cropping pattern, the project will promote less water consuming high value fruits like mango cultivation, cotton cultivation to sustain livelihood of the farmers.

15,000 farmers will be selected to implement this activity, directly benefitting 60,000 people (the household members of the selected farmers). The Implementing Entity (IE) staffs will select the potential farmers in consultation with the CCAG members. The IE staffs will arrange meeting of each CCAGs and facilitate them to identify the appropriate farmers based on the pre-selected criteria. The CCAG members will discuss in the meeting and propose the farmer's name. The IE staffswill provide training to the selected farmers on crop management (management of drought-tolerant crops including fertiliser application, soil and water management, pest and disease control, weeding and mulching, etc). This activity will be implemented in selected *upazilas* of the proposed three districts.

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[22]A rice crop planted usually in July/August, during the monsoon in areas liable to a maximum flood depth of about 0.5 meter. Harvested in November/December. Local varieties are sensitive to day length whereas modern varieties are insensitive or only slightly sensitive.

[23]A rice crop planted under irrigation during the dry season from December to March and harvested during the period from April to June. Local Boro varieties are more tolerant of cool temperatures and are usually planted early in areas which are subject to early flooding due to rise in river levels. Improved varieties, less tolerant of cool conditions are usually transplanted from February onwards. All varieties are insensitive to day length.

[24]The first part of the *kharif* season (March to June). Rainfall is variable and temperatures are high. The main crops grown are *Aus*, summer vegetables and pulses. Broadcast *Aman* and jute are planted.

Table 10: Traditional cropping patterns versus proposed crops and varieties

Season	Traditional water source	Traditional crops and varieties	Project proposed crops and varieties
Aman: July/Aug - Nov/Dec (Monsoon season)	Rain-fed agriculture	Traditional varieties *BRRI* 11 and *BRRI* 30 -Duration: 145 days - Water requirement: (Supplementary irrigation required, roughly 382 mm) - Open pollinated - Very sensitive to changes in precipitation: late onset monsoon delays planting and reduces germination; early end of monsoon causes harvest reduction and grain filling; early drought (in Sept./Oct drastically reduces yields	Project proposed varieties: *BINA*dhan -7 and *BRRI*Dhan 58 *BINA* dhan-7 is short duration (90 days). No supplementary irrigation required. - Open pollinated Variety name: *BRRI* 58 Duration: 120 days Water requirement: No irrigation is required because it can withstand in moisture stress condition for more than 15 days - Open pollinated
Boro: Dec/March - April/June	Groundwater	Name of traditional varieties: *BRRI* 28 and *BRRI* 29 - Duration: 140 days -Water requirement: 500-600 mm/season based on location - open pollinated	Wheat: *BARI* 26 - Duration: 80 days - Water requirement: 200 to 250 mm - Open pollinated variety Mustard: *BARI* 15 Duration: 80 days - Water requirement: 150 to 200 mm - Open pollinated
pre-Kharif March-June	Ground water	*Aus* rice (*BRRI* 14), jute, sesame, etc. - Long-production cycle (it is affected by late drought) Rice variety: 110-120 day duration Jute and others (sesame, sugarcane, tishi, etc.) have more than 140-day duration. Water requirement for rice: 563 mm Water requirement for Jute and others (sesame, sugarcane, *tishi*, etc.): 250-300 mm/season - Open pollinated	Mungbean: BARI 6 *- Duration: 70 days* - Water requirement: very minimum (less than 50 mm per production cycle) - can be harvested three times Open pollinated variety

In general, *Boro* rice requires twice the amount of irrigation water as wheat, maize, potato, and tomato and three times the amount of irrigation water than pulses, and 5-6 times the amount of oil seeds.

Table 11: Water requirement of traditional cropping pattern and suggested cropping pattern

Cropping pattern		Water requirement per year
Traditional	*T.Aman* (traditional variety)-*Boro-Aus*	1,445 mm
Proposed	*T. Aman*-Wheat/Mustard-Mungbean	250 mm
% of water requirement of irrigation for suggested cropping pattern compared to existing cropping pattern		17%

The table indicates that the traditional cropping pattern requires a total of 1,445 mm of irrigation for three crops, whereas suggested cropping pattern requires 250 mm irrigation which is only 17% of the irrigation required for traditional cropping pattern. So, 83% of irrigation water will be saved by changing the cropping pattern.

In Bangladesh in practice, irrigation is estimated by times, i.e., how many times irrigation is provided to a single crop. *Boro* rice requires 10-12 times irrigation, whereas wheat/mustard requires 2-3 times irrigation, i.e., less than one quarter of *Boro* rice. Thus, it was expected that if the proposed cropping pattern is implemented, at least 70% of the amount of water can be saved.

The tables below report the profitability of the crops traditionally planted by farmers and of the ones proposed by the project.

Table 12: Profitability of *Aus* paddy (traditional crop) per hectare

Costs	**Unit**	**Qt**	**Unit cost (BDT)**	**Total cost (BDT)**
Agricultural operations				
Land preparation	Ha	1	4,000	4,000
Inputs				
Seeds	kg	55	42	2,310
Urea	kg	120	18	2,160
TSP	kg	52	22	1,144
MP	kg	60	15	900
Pesticide	Ls			1,500
Herbicide	ls			400
Labour				
Hired labour	m/d	60	280	16,800
Family labour	m/d	22	280	6,160
Other costs				
Irrigation				750
Land rental				6,000
Total production cost				42,124
Production	**Unit**		**Price (BDT)**	**Value (BDT)**
Paddy	Kg	3,000	16	48,000
Byproduct (straw)	ls			5,000
Total value of produce				53,000
Profit/Ha				10,876

Table 13: Profitability of *Aman* paddy (traditional crop)

Costs	Unit	Qt	Unit cost (BDT)	Total cost (BDT)
Agricultural operations				
Land preparation	Ha	1	4,944	4,944
Inputs				
Seeds	kg	58.75	42	2,163
Urea	kg	175	18	3,152
TSP	kg	90	22	1,980
MP	kg	39.3	15	590
Pesticide				1,854
Herbicide				370
Labour				
Hired labour	Head	1	280	33,916
Family labour	Head	11.25	280	3,152
Other costs				
Irrigation				00
Land rental				18,000
Total production cost				*70,794*
Production	**Unit**		**Price (BDT)**	**Value (BDT)**
Paddy	Kg	5,130	16.25	83,362
Byproduct (straw)	Ls			5,130
Total value of Produce				88,492
Profit/Ha (BDT)				17,699

Table 14: Profitability of *Boro* paddy (traditional crop)

Costs	Unit	Qt	Unit cost (BDT)	Total cost (BDT)
Agricultural operations				
Plowing	Ha	1	4,944	4,944
Inputs				
Seeds	kg	58.75	42	2,163
NPK				
Urea	kg	175	18	3,152
TSP	kg	90	22	1,980
MP	kg	39.3	15	590
Pesticide				1,854
Herbicide				370
Labour				
Hired labour	Head	130	280	36,400
Family labour	Head	11.25	280	3,152
Other costs				
Irrigation				8,652
Land rental				18,000
Total production cost				*81,930*
Production	**Unit**		**Price (BDT)**	**Value (BDT)**
Paddy	Kg	6415	20	80,340
Byproduct (straw)	Ls			5,700

Total value of produce				86,040
Profit/Ha (BDT)				4109.4

Table 15: Profitability of wheat (proposed crop)

Costs	**Unit**	**Qt**	**Unit cost (BDT)**	**Total cost (BDT)**
Agricultural operations				
Plowing	Ha	1	4500	4,500
Inputs				
Seeds	kg	120	32	3,840
NPK				
Urea	kg	220	18	3,960
TSP	kg	150	22	3,300
MP	kg	100	15	1,500
Gypsum		100	10	1,000
Boric Acid		7	100	700
Pesticide				1,500
Herbicide				400
Labour				
Hired labour	Head	85	280	23,800
Family labour	Head	10	280	2,880
Other costs				
Irrigation	Time	2		3,000
Land rental				18,000
Total production cost				*66,880*
Production	**Unit**		**Price (BDT)**	**Value (BDT)**
Wheat	Kg	3,000	30	90,000
Byproduct (straw)	Ls			10,000
Total value of produce				100,000
Profit/Ha				33,120

Table 16: Profitability of Mustard (proposed crop)

Costs	**Unit**	**Qt**	**Unit cost (BDT)**	**Total cost (BDT)**
Agricultural operations				
Plowing	Ha	1	4,500	4,500
Inputs				
Seeds	kg	7	50	350
NPK				
Urea	kg	250	18	4,500
TSP	kg	180	22	3,960
MP	kg	100	15	1,500
Gypsum		180	10	1,800
Boric Acid		7	100	700
Pesticide				1,500
Labour				
Hired labour	Head	50	280	22,400
Family labour	Head	10	280	2880
Other costs				
Irrigation	Time	2		1,800
Land rental				18,000

Total production cost				*55,490*
Production	**Unit**		**Price (BDT)**	**Value (BDT)**
Mustard	Kg	1,700	40	68,000
Byproduct (straw)	Ls			5,000
Total value of produce				73,000
Profit/Ha	Ha			17,510

Table 17: Profitability of Mung (proposed crop)

Costs	**Unit**	**Qt**	**Unit cost (BDT)**	**Total cost (BDT)**
Agricultural operations				
Plowing	Ha	1	4,500	4,500
Inputs				
Seeds	kg	25	90	2,250
NPK				
Urea	kg	44	18	792
TSP	kg	100	22	2,200
MP	kg	40	15	600
Boric Acid		7.5	100	750
Pesticide				2,200
Labour				
Hired labour	Head	50	280	14,000
Family labour	Head	10	280	2,880
Other costs				
Irrigation	-	-		-
Land rental				18,000
Total production cost				*48,222*
Production	**Unit**		**Price (BDT)**	**Value (BDT)**
Mung	Kg	1,000	60	60,000
Byproduct (straw)	Ls			5,000
Total value of produce				65,000
Profit/Ha				16,778

Table 18: Profits of individual crops per hectare

Traditional crops	BDT /ha
Aus paddy	10,876
Aman paddy	17,699
Boro paddy	4,109
Project proposed crops	
Wheat	33,120
Mung	16,778
Mustard	17,510

The project will promote alternative cropping patterns, which are based on the above crops. A comparative analysis of traditional versus proposed cropping patterns is included in the following table.

Table 19: Comparative analysis of cropping patterns profitability

Traditional cropping pattern	Profit (BDT) per hectare
Aus-Aman-Boro	32,684
Project proposed cropping patterns	
Aman-Wheat-Mung	67,597
Aman-Mustard-Mung	51,987

Both traditional cropping patterns and project proposed cropping patterns are based on three production cycles per year. However, the profit per hectare of the *Aman*-wheat-mung cropping pattern (proposed by the project) is 107% higher than the traditional cropping pattern, and the *Aman*-mustard-mung cropping pattern (also proposed by the project) is 59% higher than the traditional cropping pattern. This shows that with proper technical assistance, farmers can easily be incentivised to change cropping patterns.

The water requirements of the proposed cropping patterns are much lower than that of the traditional cropping patterns (see previous analysis). In addition, the proposed cropping patterns include a leguminous crop (mungbean), which fixes nitrogen in the soil, thus contributing to soil fertility.

7.3 Operation and Maintenance Plan

The project will apply technical means for (a) harvesting of rainwater during monsoon (in natural streams/khals, ponds, and on rooftops), and (b) collecting/directing such water in micro-scale reservoirs, by passing through pipelines and shafts. Moreover, natural streams and ponds will be re-excavated to increase water holding capacities of such reservoirs. All these activities are subject to weathering effect. Moreover, the filtering materials within the shafts are likely to be clogged because of the presence of dirt and sediments that will flow along rainfall runoff. This is why, efforts must be made to maintain the systems during the implementation phase and beyond.

The piloting of MAR systems has been accomplished by DASCOH, an NGO based in Rajshahi district, under the aegis of BMDA. The NGO is provided with technical support from both the BMDA and University of Rajshahi. The operation and maintenance (O&M) activities are supervised by the collective efforts of these organizations, all under the leadership of BMDA.

The household-based MARs will be requiring maintenance, just once in a year – only at the beginning of the monsoon. The MARs involving designated ponds and concrete building structures for rooftop MARs, cleaning/washing of filtration material and retrofitting piping system need to be checked at the beginning of every monsoon season and also once during the mid-monsoon (say, between 1 and 15 of July every year).

The chance of erosion of edges of the banks of re-excavated ponds and streams could be avoided if these are kept under surveillance and maintenance. The BMDA-led technical team suggests a three-time surveillance during each monsoon season and subsequent maintenance.

Each CCAG will be asked to nominate/elect at least three members as volunteers for the O&M activities. The BMDA and University of Rajshahi technical team will provide training involving such volunteers. PMU will organize such training sessions, one in every district. PKSF technical team will supervise and provide technical support during the course of the training for O&M.

However, identification of actors representing each CCAG and scheduling their activities will not be adequate to get the O&M actions done. These micro-level efforts will require mobilization of necessary funds. Since the MAR application is a fairly new initiative in Bangladesh, the costs for O&M spent from pilot activities must be taken into consideration. For MAR system, each maintenance routine involving cleaning of filtration material requires about BDTk 2,500 to 3,000. For identification of points of erosion and potential bank failure in ponds, the cost is BDTk 1,000 per pond and BDTk 2,000 per 2 kilometers length of stream/khal.

The BMDA offer water supply services and they charge a flat rate of BDTk 50 per household, irrespective of social and economic standing of the benefit recipient household. The stakeholder consultations provided insights into raising fund by the participation of service recipients. It is found that, even the poorest has willingness to pay up to BDTk 100 per month, which is roughly about 1.4% of the monthly average household expenditure of a household of 4 to 5 persons belonging to poor strata of the society in Barind area. When asked, these poorest people indicated that they would be happy to pay any amount between BDTk 50 to 70, which indicates that their ability to pay is within the ballpark of 0.7 to 1.0% of their monthly average expenditure.

Since it is assumed that for both rooftop and pond-based MAR, at least 100 households will be sharing benefits of water availability for drinking and supplementary irrigation, if not directly considered to be the long-term beneficiaries of replenishment of GWT. If these households are levied BDTk 70 per month (i.e, 1% of average monthly expenditure of a household belonging to the poorest class, falling within their ability to pay), the amount generated will be more than sufficient to cover the occasional costs for O&M activities as outlined above.

It is proposed that each CCAG will be given responsibility to raise the amount from their participating households. The fund thus generated will be kept by opening a bank account, which will be operated by selected members. The NGO as the Partner Organization will help them and guide, if needed for the maintenance of the fund. The CCAG sub-committee on O&M, as proposed earlier, will identify dates of O&M activities and request NGO supervising personnel to help withdraw fund from the bank account and mobilize. The overall supervision will be provided by the technical team, which is led by BMDA and the University of Rajshahi.

Since at least 100 households will be directly benefitting from each pond, the total amount raised per re-excavated pond will be adequate to cover O&M costs. The net amount levied per household for O&M will be within their willingness to pay as well as ability to pay, as it has been discussed in the consultative meetings.

Table 20: Operation and Maintenance Plan

Intervention	Timeframe of maintenance interventions	Responsibility	Source of fund	Remarks
Ponds	3 times during monsoon (July, August and September)	• BMDA will provide technical support • CCAG members will maintain and operate ponds	BMDA will apply their existing mechanism, i.e., pricing of water for raising funds	IEs will ensure implementation of the plan as they continue their financial support to the beneficiaries from their core programme.
Canal	3 times during monsoon (July, August and September)	• BMDA will provide technical support • CCAG members will maintain and operate the re-excavated canals	BMDA will apply their existing mechanism, i.e., pricing of water for raising funds	
Artificial Ground water recharge	Annual	• BMDA will provide technical support • CCAG members will maintain and operate MARs	BMDA will apply their existing mechanism, i.e., pricing of water for raising funds	
Drought adaptive agriculture	Based on crop season	• Farmers • Department of Agriculture Extension (DAE) will provide necessary technical support under their regular duties		

7.4 Theory of Change, barriers and challenges

As the monsoon period shifts to become shorter under climate change, there are more consecutive dry days that lead to drought. Drought causes a decrease in agricultural output leading to loss of livelihoods and food insecurity as well as direct health impacts from lack of access to clean water or sourcing unsafe water for drinking.

The government policy response is maladaptive, relying on large infrastructure projects (e.g., ground water irrigation infrastructure by BMDA) to install deep tube-wells that abstract ground water from underlying aquifers for irrigation and drinking. This leads to over-extraction of groundwater and lowering of GWT and eventually will lead to the functional extinction of the aquifer. Many old tube-wells are broken (because of lack of maintenance operations), which reduces access to clean water. As a consequence, women must walk miles to find water in dry season. Traditional agriculture depends on a large quantity of available water through the practice of flood irrigation. Weak community level institutions are not able to adapt to these impacts while communities have a low adaptive capacity to respond, neither knowing how to adapt their agriculture to fit new environmental conditions nor to organise to develop water storage systems or implement water management. Gender inequalities that resist women from decision making exacerbate the situation leading to high vulnerabilities and climate risks for poor households.

There is a need to increase the adaptive capacity of communities and community institutions that include gender equality so that they are enabled to develop local solutions to climate issues that include good water management and maintenance of infrastructures, for household and agricultural use. Households need closer access to safe sources of water. Furthermore, traditional agricultural practices are maladaptive to current and future climate and hence, water conservation in agriculture that significantly reduces the overall water demand is crucial. However, water supply must be sustainable so that there is truly a paradigm shift towards sustainable water solutions before GW resources are severely depleted.

This project will ensure good management and scaling up potentials by enabling local NGOs through capacity building so that they can liaise with communities and provide capacity building. In order to build adaptive capacity within vulnerable communities, local NGOs will organise them into self-help groups and train them to manage water resources infrastructures in drought appropriate agricultural techniques.

To reduce the amount of water needed by crops, this project aims to identify and promote the use of low water consuming crops for the dry season, which is expected to reduce irrigation needs by up to 70% in the winter season (30% for year-round irrigation).

To provide sustainable irrigation of water for new adaptive crops, this project aims to rehabilitate dysfunctional community ponds and that need only minor improvement to store water in the dry season (to be used for irrigation purposes).

In order to address the sustainability of the water resources, this project will implement Managed Aquifer Recharge (rainwater directed through tubes to aquifer) systems, which are expected to replenish groundwater required for about 50,000 beneficiaries.

Potential risks to the project are that the government's projects for drought management enable users to over-extract ground water resources before this project is able to have significant positive effects on ground water. The project will engage government's relevant oganisations to minimise this risk. In addition, communities may not adapt to the new crop system and revert to traditional forms, which is unlikely given the advantages of the proposed cropping patterns and varieties.

<u>Low level of technical and institutional capacity of government institutions to promote a sustainable water resources management</u>

Over-exploitation problems of groundwater are not properly addressed by relevant government authorities while surface water is scarce during drought periods, exploitation of ground aquifers keeps reducing the groundwater table. This is both caused by a lack of knowledge regarding alternative technical solutions to address over-exploitation problems of groundwater resources and by a lack of financial resources from relevant authorities. Also, storage and use of surface water for agricultural purposes are not properly promoted by relevant authorities. As a consequence, exploitation of groundwater resources increases.

The project will promote MAR as practical alternative solution to address groundwater depletion problems. MARs have been piloted on coastal zones and Barind areas but they are not promoted because primarily there is no authority to promote MAR in the country. Secondly, the government has adopted a national MAR strategy but finance is not ensured yet. There is also a lack of available technical experts for mass scaling up of the MAR. These problems remain nationwide including in the proposed districts.

Weak capacities of development actors to propose effective solutions for drought adaptation

The intervention area is characterised by a significant presence of governmental and non-governmental organisations (NGOs) working on a variety of development topics, including disaster risk reduction and livelihoods diversification. However, there is a clear lack of capacities in mainstream actions addressing climate change challenges in development interventions, especially with regards to drought adaptation. One main reason is the fact that climate change adaptation is an emerging issue. The local institutions and actors have limited understanding of how to address adaptation in the local context. Besides, studies on effectiveness and efficiency of climate change adaptation options are very limited which ultimately limits understanding of adaptation issues. It is also a technical issue of analysing climate change information for designing a project. This specialised knowledge and experience are also limited. In addition, drought resilient indicators are not defined. So practitioners do not understand where their interventions are effective in terms of adaptation to drought.

Low community awareness on adaptive responses to climate change impacts

Community awareness about alternative options to address climate change problems (especially droughts) is very low in the project area. The project will raise awareness among the selected communities in monthly group meetings of the CCAGs on climate change issues. Moreover, technical knowledge of alternative and less water consuming cropping patterns as well as knowledge of drought resistant varieties is very limited among farmers.

The project will address the above-mentioned barriers by scaling up the results and lessons learned from previous relevant projects like the Community Climate Change Project (CCCP) and the Livelihood Adaptation to Climate Change project (LACC). The former proposed simple management systems and technologies to make local communities resilient to drought by increasing access to safe water. The latter (implemented by UNDP and funded by UK Department of International Development and by the European Union) designed location-specific adaptation strategies. It implemented more than 300 demonstrations and field testing out and identified different adaptation options.

More specifically, this project will address the above-mentioned barriers by improving technical and institutional capacities to address over-exploitation problems of the groundwater aquifer among relevant government and non-government authorities. More precisely, the project will enhance capacity of the BMDA by establishing climate change unit within the same organisation and providing training and technical support for mainstreaming climate change in development activities. The establishment of an MAR centre under the Ministry of Water Resources will ensure that the sustainable recharge aquifer technique is implemented by the project and further scaled-up. Community awareness on climate change and related droughts will be promoted by establishing Climate Change Adaptation Groups (CCAGs) and farmers will be trained and supported to adapt to droughts and climate change. More specifically, drought-tolerant crops and varieties will be promoted to address early droughts, reduce the duration of the crop life-cycle and reduce water requirements.

Figure 26 reports the Theory of Change of project, thus showing how the activities proposed address the described barriers and lead to a change of results up to the project goal.

Figure 31: Theory of Change Diagram

8 Implementation Arrangement

8.1 Stakeholder analysis/Consultations/Engagement Plan

This project has been designed based on the experience gained through the implementation of the Community Climate Change Project (CCCP).During the implementation of the project, many consultation meetings were held at the community level (October, 2012 to December, 2016). The purpose of these meetings was to monitor project progress, implementation quality and quantity, effectiveness and other project level indicators. This information was documented in evaluation reports and the book on “Pathways to Resilience: CCCP Experiences.” This experience provides the basis for developing the Extended Community Climate Change Project-Drought (ECCCP-Drought). In addition, mid-term evaluation, final evaluation and World Bank’s mission reports conducted additional consultations at the community level. Information from all of these communications were used to develop this proposal. In addition, PKSF organised a stakeholder consultation meeting on the draft project documents of ECCCP-Drought involving experts from government and non-government organisations. This information is also used in this proposal. The latter meeting resulted in the following suggestions:

- The project should consider AEZ (Agro-Ecological Zone. There are 30 AEZs in Bangladesh) for selecting the project area
- Climate-smart agriculture and resilient infrastructure should be incorporated
- Tree plantation and community savings for the climate vulnerable people
- Increasing savings of the vulnerable community
- Excavate dug-wells for drinking water and irrigation
- Ensure availability of seeds of drought-tolerant varieties
- Re-excavate ponds and canals in the water-scarce areas
- Carry out morphological surveys for identifying canals and ponds for re-excavation
- Livelihood options should be open and demand-driven
- Link the project with existing micro-credit programmes of PKSF

PKSF also presented this proposal to the Advisory committee of the NDA for obtaining the ‘No Objection Letter’. The advisory committee to the NDA comprises government, non-government, academia and climate change experts. The committee also provided feedback which is incorporated in the proposal.

Stakeholder Engagement Plan

Stakeholder engagement during the project implementation will begin at the inception workshop to be held at the initial stage of the project. PKSF will organise a project launching ceremony at national level where NDA representatives, representatives of relevant government ministries and departments including but not limited to Department of Agricultural Extension (DAE), Department of Livestock (DoL), Department of Public Health and Engineering (DPHE), Department of Environment, Bangladesh Climate Change Trust, NGOs and civil societies will be invited to attend the ceremony. However, the three outcomes of the project will have the following stakeholders:

Component/Outcome 1: Local institutions and communities equipped with knowledge and experience on addressing climate change induced drought

This outcome will engage multiple stakeholders ranging from national level down to community level. The PMU at PKSF will lead the activities of the outcome. PKSF, as AE, will provide guidance on carrying out the baseline study and indicators. It will hire national level consultants who are experts in the climate change adaptation sector. It will engage Economic Relation Division (ERD) as the NDA to GCF for Bangladesh as respondents of layers of interviews and for sharing the research results. It will also engage the Department of Environment and other relevant climate change actors including non-government organisations, IEs, LGIs, beneficiaries and civil society members. Finally, activities under this outcome will engage communities in drought vulnerable areas to capture their views and status in terms of addressing climate change.

This component will involve PKSF, BMDA, other local government bodies like DPHE, NGOs who will take part in the screening process to become implementing entities of the project, local government representatives, union parishad representatives and the local community. Local government representatives will help to select vulnerable *upazilas* and unions while union parishad representatives will help select villages and vulnerable communities. The local community will help selecting vulnerable households, and finally the selected households will take part in the training, vulnerability assessment, preparing adaptation action plan and implement adaptation technologies.

Component/Outcome 2: Increased availability of surface and ground water for irrigation and drinking

This outcome will involve local offices of the Department of Public Health and Engineering (DPHE), Water Resources Planning Organisaiton (WARPO) under the Ministry of Water Resources, Barind Multipurpose Development Authority (BMDA), Proposed MAR centre, Bangladesh Water Development Board (BWDB), CCAG members, contractors, union parishad representatives and other local community. The IE staff will ensure participation of these stakeholders during implementation of the activities under this outcome.

Component/Outcome 3: Drought resilient livelihoods created through sustainable agricultural productivity

This outcome will involve the selected beneficiaries, local offices of the Department of Agricultural Extension (DAE), Bangladesh Agricultural Development Corporation (BADC) and BMDA.

Stakeholder engagement will be performed using best practices and principles so that the project demonstrates:

- **Commitment** when the need to understand, engage, and identify the community is recognised and acted upon early in the process;
- **Integrity** through mutual respect and trust;

- **Respect** for rights, cultural beliefs, values, and interests of stakeholders and affected communities are recognised;
- **Transparency** when community concerns are responded to in a timely, open, and effective manner;
- **Inclusiveness** when broad participation is encouraged and supported by appropriate participation opportunities; and
- **Trust** through open and meaningful dialogue that respects and upholds a community's beliefs, values, and opinions.

Table 21: Stakeholder engagement strategies

Activity	Objectives of Engagement	Target stakeholders	Proposed Strategy for stakeholder engagement of stakeholders	Timing
Activity 1.1.1: Establishment of climate Change unit at the Barind Multipurpose Development Authority (BMDA)	Enhance capacity of the government on climate change-induced drought management in Bangladesh.	Ministry of Agriculture, Ministry of Water Resources, Economic Relation Division (ERD) Barind Multipurpose Development Authority (BMDA), Department of Agricultural Extension, Bangladesh Water Development Board and Water Resources Planning Organisation (WARPO).	1. Project website, online monitoring system, google based GIS mapping of project information, workshops, seminars. Another preferred medium is email. 2. For official communications, these written communications can be sent via email and hard copy via courier or post office. 3. Regular project updates are to be provided on a monthly and/or quarterly basis through meetings (face-to-face and/or Skype/zoom) at the project level. One assigned focal person and their alternate should be assigned by each organisation to the project to ensure continuity. 4. At the national level, project updates should be shared through seminars and websites. 5. Annual presentations to stakeholders should also be conducted by the EE and Implementing Partners.	Yr.1, 2, 3 & 4
Activity 1.1.2: Establishment of an MAR centre	Enhance capacity of the government on implementation of MAR strategy in the country.	Ministry of Agriculture, Ministry of Water Resources, Economic Relation Division (ERD)	1. Official Letters. These written communications can be sent via email and in hard copy via courier or post office. 2. Regular project updates are to be provided on a monthly and/or quarterly basis through meetings	Yr.1, 2,

Activity	Objectives of Engagement	Target stakeholders	Proposed Strategy for stakeholder engagement of stakeholders	Timing
		Barind Multipurpose Development Authority (BMDA), Department of Agricultural Extension, Bangladesh Water Development Board and Water Resources Planning Organisation (WARPO).	(face-to-face and/or Skype/zoom) at the project level. One assigned focal person and their alternate should be assigned by each organisation to the project to ensure continuity. 3. At the national level, project updates should be shared through seminars and websites.	
Activity1.2.1: Real Time Evaluation (RTE) study	Field level data and information collection on the impacts of project interventions.	Implementing Entities (IEs), CCAG members, other community people, Union Parishad (the lowest administrative unit of the country), BMDA, local office of the Department of Agricultural Extension (DAE) and consultants.	1. For official letters, these written communications can be sent via email and in hard copy via courier or post office. 2. MoUs could be signed with consultants for carrying out studies. 3. At the national level, project updates should be shared through seminars and websites.	Yr.1, 2, 3 & 4
Activity1.2.2: Analyse results and develop	To develop a knowledge database and	PKSF, Economic Relation Division (ERD), consultants	1. For official letters, these written communications can be sent via email and in hard copy via courier or post office.	Yr. 1

Activity	Objectives of Engagement	Target stakeholders	Proposed Strategy for stakeholder engagement of stakeholders	Timing
knowledge database of intervention impacts	lessons learned from the impacts of adaptation interventions.	and Implementing Entities.	2. MoUs could be signed with consultants for carrying out studies 3. At the national level, project updates should be shared through seminars and websites.	
Activity 1.2.3: Training to NGOs on climate change	To increase institutional capacity of the selected NGOs on climate change issues.	PKSF, Economic Relation Division (ERD), selected NGOs.	1. Share best practices among IEs, CCAGs needs to be conducted. Peer-to-peer learning will contribute to capacity building and scaling up of the project within the Barind tract and across drought-prone areas. 2. Take initiatives for continued updating of evaluation data, maintenance of the wells where they are located, holding regular meetings, and capacity building and training activities will hold the interest and support of local communities, IEs even beyond the project life. 3. Conduct regular meetings and work planning with community stakeholders to increase transparency and ownership. 4. Developing common communication materials and branding for unified messaging that will sustain the interest of end-users and stakeholders at the *upazila* and community levels. 5. Closer coordination among PKSF and IEs in undertaking field work and site visits at the project sites is needed.	Yr. 1

Activity	Objectives of Engagement	Target stakeholders	Proposed Strategy for stakeholder engagement of stakeholders	Timing
			6. Ensure active participation and engagement in all project activities at the project sites to ensure continuing support.	
Activity 1.2.4: Training on CC issues and project management	Ensure effective implementation of the project.	PKSF and IEs	1. Prepare training plan. 2. Send invitation through official letters. 3. Arrange physical trainings.	Yr. 1
Activity 1.2.5: Organise knowledge sharing workshops and seminars	To share the learning of the project with different stakeholders in Bangladesh.	PKSF, ERD, government ministries and departments, civil society representatives.	1. Send invitation to training participants through official letters. 2. Prepare knowledge documents and power point presentations. 3. Organise workshops. 4. Prepare workshop proceedings and share through websites.	Yr. 1, 2, 3, 4
Activity 1.3.1: Beneficiary selection, group formation and mobilisation	To provide support services to the selected community.	PKSF, IEs, and CCAG members.	1. Consult with upazila level stakeholders for union selection. 2. Consult with union parishad representatives and other stakeholders for village selection. 3. Discuss in a large groups with community people. 4. Focused group discussion with key informants. 5. Prepare short list of beneficiaries for activity 3.1.1 and 3.1.2 (for other activities, all the people within the command area of MAR, pond	Yr. 1, 2

Activity	Objectives of Engagement	Target stakeholders	Proposed Strategy for stakeholder engagement of stakeholders	Timing
			and canals will be direct beneficiaries) 6. Form CCAG groups	
Activity 1.3.2: Develop beneficiary's socio-economic profiles	To involve IEs to keep primary records of selected beneficiaries.	PKSF, IEs, and CCAG members.	1. Visit households of the select beneficiaries. 2. Interview beneficiaries for filling the profile format. 3. Data entry and analysis for information management.	Yr. 1
Activity 1.3.3: Arrange monthly group meetings on climate change issues of CCAG	To involve IEs to enhance capacity of communities against drought.	PKSF, IEs, and CCAG members.	1. Prepare content, flip chart and other tools for meetings. 2. Facilitate the CCAG members for conducting the meeting.	Yr. 1
Activity 1.3.4: Training of beneficiary groups	To provide training to the CCAG members.	PKSF, IEs, CCAG members	1. Prepare training plan. 2. Sent invitation to the participants. 3. Arrange venue and accommodation (if required). 4. Deliver training using audio visual techniques.	Yr. 1, 2, 3, 4
Activity 1.3.5**:** Organize exchange visits for CCAG members and IEs' staffs	To increase communities' understanding of climate change	PKSF, PMU, local consultants, IEs, and CCAG members	1. Identify the best practices. 2. Select participants for attending the exchange visits. 3. Meetings and discussions and activity visit. 4. Prepare reports and share those appropriatly.	Yr. 1, 2

Activity	Objectives of Engagement	Target stakeholders	Proposed Strategy for stakeholder engagement of stakeholders	Timing
Activity 2.1.1: Ponds re-excavation	To ensure proper implementation of the activity	PKSF, PMU, local consultants, IEs, and CCAG members	1. Organize meetings with relevant stakeholders including BMDA, Upazila Nirbahi Officer (UNO) and other government and non-government organisations. 2. Select ponds in consultation with community people. 3. Hire local contractors or organize local people for earthwork by the IE 4. Monitor earthwork activities.	Yr. 2, 3, 4
Activity 2.1.2: Canals re-excavation	To ensure proper implementation of the activity	PKSF, IEs, selected beneficiaries, BMDA, local contractors, local government representatives etc.	1. Organize meetings with relevant stakeholders including BMDA, Upazila Nirbahi Officer (UNO) and other government and non-government organisations 2. Select ponds in consultation with community people. 3. Hire local contractors or organize local people for earthwork by the IE 4. Monitor earthwork activities	Yr. 1, 2, 3, 4
Activity 2.2.1: Installation of rooftop managed aquifer recharge system	To ensure effective implementation of the activity	PKSF, IEs, Bangladesh Water Development Board (BWDB), BMDA, contractors, and selected beneficiaries	1. Select institutions and houses for MAR through consultations. 2. Hire contractors for installation. 3. Monitor, supervise the activities and report accordingly.	Yr. 1, 2, 3, 4

Activity	Objectives of Engagement	Target stakeholders	Proposed Strategy for stakeholder engagement of stakeholders	Timing
Activity 2.2.2: Installation of recharge well for ground water recharge in ponds	To ensure effective implementation of the activity	PKSF, IEs, Bangladesh Water Development Board (BWDB), BMDA, contractors, and selected beneficiaries	4. Select institutions and houses for MAR through consultations. 5. Hire contractors or local technician for installation. 6. Monitor, supervise the activities and report accordingly.	Yr. 1, 2, 3, 4
Activity 3.1.1: Promotion of drought-adaptive cropping patterns, crop varieties	To ensure effective implementation of the project	PKSF, IEs, BMDA, Department of Agricultural Extension, Bangladesh Agriculture Development Corporation (BADC), contractors, and selected beneficiaries	1. Select crop varieties in consultation with Department of Agriculture Extension (DAE) and local farmers. 2. Provide training to the farmers. 3. Purchase agricultural inputs including seeds and fertilizers by the IES. 4. Cultivate the selected crops. 5. Monitor, supervise the activities and report accordingly.	Yr. 1, 2, 3, 4
Activity 3.1.2: Promotion of drought-adaptive fruit cultivation	To ensure effective implementation of the activity	PKSF, IEs, selected farmers, DAE, and BADC, etc.	1. Select species in consultation with Department of Agriculture Extension (DAE), Bangladesh Agriculture Research Institute (BARI) and local farmers. 2. Provide training to the farmers. 3. Purchase agricultural inputs including seeds and fertilizers by the IES.	Yr. 1, 2, 3, 4

Activity	Objectives of Engagement	Target stakeholders	Proposed Strategy for stakeholder engagement of stakeholders	Timing
			4. Cultivate the selected crops. 5. Monitor, supervise and report accordingly.	

8.2 Implementation arrangement and governance of the project

PKSF will serve as both Accredited Entity (AE) and Executing Entity (EE). PKSF's AE and EE functions will be well separated internally in order to differentiate the Project supervision and the Project coordination functions. As AE, PKSF will ensure compliances for the whole project implementation including fiduciary standards and ESS. As the Executing Entity, PKSF will take responsibility for the effective implementation and coordination of all Project components through a dedicated team. PKSF will be in charge of ensuring coordination of the planning and implementation of project activities financed by GCF proceeds.

PKSF will establish a Project Management Unit (PMU) to handle the coordination and implementation of the project. The role of the PMU is to ensure that work on the three components is conducted consistently. The PMU will be responsible for awarding contracts, supervising the activities implemented by the procured parties (government, NGOs, private actors) and monitoring and evaluating compliance with safeguards. The PMU will work in close collaboration with various ministries and government agencies, which have a key role to play in supporting implementation of certain project activities. The PMU will be headed by a Project Coordinator (PC) and PKSF staff members. The PC will directly report to a Deputy Managing Director (DMD), who is the focal person to GCF for PKSF and the Contact Person at PKSF for the GCF Secretariat and NDA. The DMD will review the submissions of Annual Performance Report (APR) and Intermediary Unaudited Financial Reports (IUFR), make queries and approve project documents to be submitted to GCF.

Involved government agencies (BMDA and Ministry of Water Resources) will designate a focal point for the project implementation and monitoring. The PMU will meet every week or more often, if necessary, to monitor project activities.

A team of technical reviewers will be engaged when required to appraise projects. Technical experts will review the project locations. PKSF, as EE, will monitor the implementation activities of IEs through PMU. PKSF will adhere to Results-Based Monitoring (RBM) system to ensure reaching the project goals efficiently and effectively.

Implementation of GCF funded activities will also be via contracts with implementation entities (in compliance with PKSF procurement policies and procedures). PKSF will select these partners through a call for Expression of Interest (EoI) (procured parties) to perform services against a set of general and technical criteria that would include, inter alia, expertise in the technical field and past successful engagement with PKSF. Along the same lines, the framework for collaboration will be developed at the beginning of each annual exercise through the development of complementary/combined annual work plans and approved budgets (AWPB).

PKSF will contract IEs to implement the project activities at community level. PKSF’s procurement policies and procedures will be used to contract IEs.

IEs will monitor the output activities, outcome and impacts of the activities, as well as impacts on environment and society. They will ensure proper gender participation in the project field staff and among beneficiaries. They will report to PKSF PMU on the progress of the project. The IEs will be required to employ a dedicated monitoring officer, who will report to the Chief Executive or senior official of the IE.

In order to select IEs, a procurement committee will be formed as per PKSF's procurement policy. The committee will invite Expression of Interest (EOI) from the IEs using two national newspapers (both Bangla and English). The eligible criteria for submitting the EOI are:

a) Valid legal documents including formal registration.
b) Permanent presence of the organisations in the project areas.
c) At least five years of experience in implementing climate change related projects or programmes.
d) A good track record of financial turnover of at least BDT 1 crore (10 million) annually for the last three years.
e) Must meet PKSF's assessment criteria, which will be detailed during the implementation stage and will include financial efficiency, operational efficiency, growth indicators, financial strength & risk management, accounting & internal control system, social performance, human capacity and governance.
f) Organisations will be ineligible on the grounds of involvement in any Money Laundering and Terrorist Financing[25].

The project will also directly sign a Memorandum of Understanding (MoU) with BMDA for providing technical and advisory support to the implementing entities. BMDA will provide technical support particularly in implementing ponds and canals related activities. BMDA will provide engineering design of the ponds and canals and will support the preparation of technical specifications of the ponds and canals to procure works. BMDA will be involved in Tender Opening Committee (TOC) and Tender Evaluation Committee (TEC) to implement works needed for ponds and canals rehabilitation. In order to ensure quality, BMDA will monitor and supervise implementation of works. Finally, BMDA will conduct quality tests of ground water (recharged through MAR) in its own laboratory.

BMDA will be paid consultancy fees for providing this technical support, which is included in the activity budget. A Memorandum of Understanding (MoU) between BMDA and PKSF will be signed clearly mentioning the tasks to be done by BMDA and the payment schedule.

The following flow-chart represents the implementation arrangement at PKSF level:

[25] Before final selection, PKSF physically visit the organisations and examine all documents including accounts and finances for examining strength of financial capacity and whether the organisations have any involvement in illegal financial transaction.

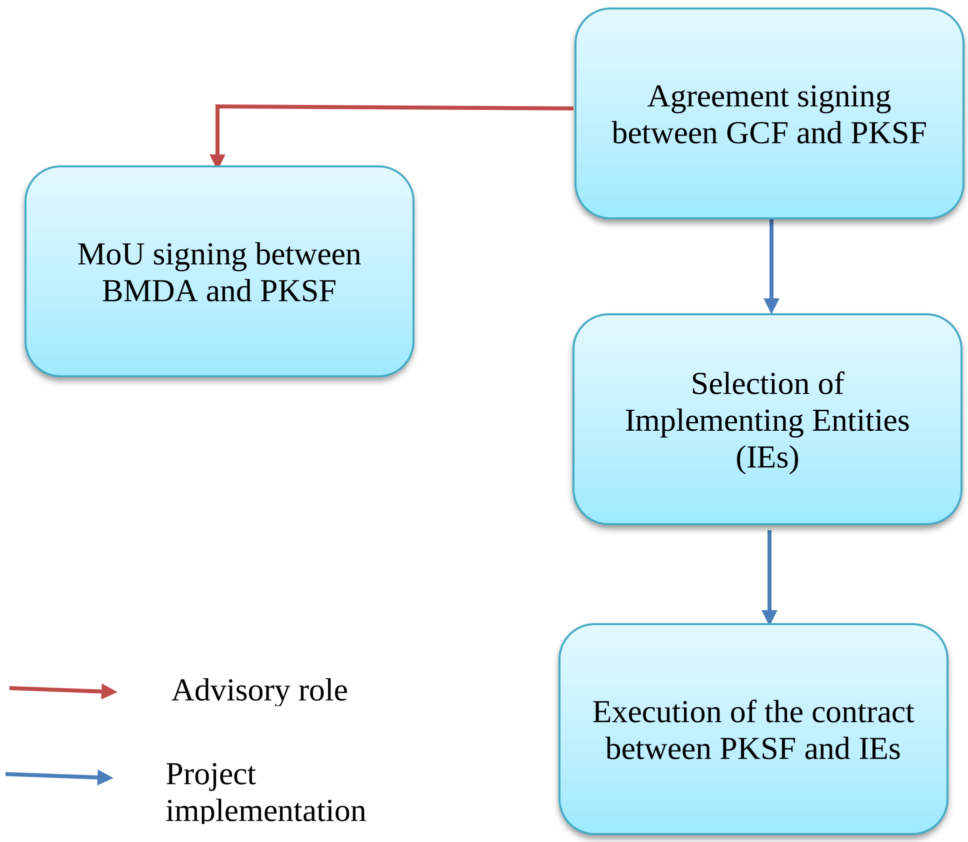

Figure 32: Implementation arrangement

Funds will be directly disbursed to PKSF from GCF. PKSF will receive the GCF proceeds in a special account in the name of 'GCF-PKSF project' in a commercial bank. PKSF will reimburse the fund to the implementing entities based on satisfactory performance. PKSF will provide USD $4.5 million as loan to co-finance the project. These funds will be used to promote climate resilient agriculture in the drought-prone areas. 15,000 selected farmers will receive loans. Existing credit staffs of the IEs (IEs must have credit programmes in the selected areas) will disburse loans based on an assessment of loan demands in the agriculture section of the project areas.

Fund flow of the project:

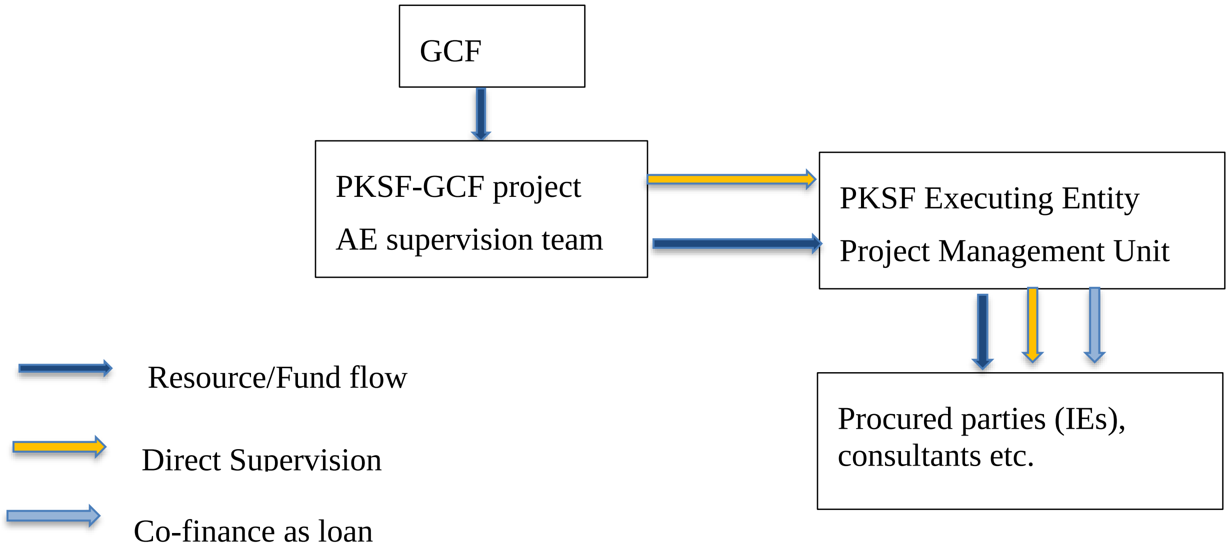

Figure 33: Fund flow diagram of the project

9 Safeguard issues

9.1 Environmental Impacts

The proposed project has selected community-based adaptation activities that have insignificant environmental damages as assessed during implementation of CCCP. This project has some similar activities that were demonstrated during the Community Climate Change Project (CCCP), such as: re-excavation of existing ponds and drought-resilient crop production. This project proposes an innovative intervention like MAR models. This will improve overall environmental conditions by improving ground water recharge against current over-exploitation. The project also proposes canal re-excavation to store rainwater for irrigation. The monitoring reports of PMU and the World Bank (the fiduciary manager of the CCCP) did not identify any impacts that would require further due diligence and management planning. Most of the impacts were managed through awareness and motivation of the project participants. The pond and canal re-excavation could have impacts on land uses once it would normally require land for storing re-excavated soil. However, in this project, the re-excavated soil will be fully used to construct the pond and canal dyke in order to mitigate run-off and siltation of the pond and hence no extra land will be required to put the re-excavated soil. For management of wastewater for tube-wells, the project will construct soak well with each tube-well.

9.2 Social Impacts

The project will not require acquiring land or other properties. The beneficiaries will implement the agriculture related activities in their own land. The project will implement a cropping pattern that makes extra income. Both women and men will engage in these types of activities. They will receive training from the project interventions.

The Adaptation Support Mechanism will always be lower than the number of eligible people in a location. Therefore, the major risk is beneficiary selection bias that may exclude socially marginalised people. This will be mitigated by adopting clear cut selection criteria, utilisation of participatory methodologies, a robust mechanism to address complaints and grievances (see section 9) regularly monitored by the project drawing guidance from the Project Management authority. Community driven planning and construction creates transparency and accountability to those most incentivised to demand accountability: the beneficiaries themselves. This method of selection of beneficiaries was successful in the previous CCCP.

Sexual and gender-based violence is another risk which these women and adolescent beneficiaries may face during the collection the water from far away. The pond and re-excavation, and MAR system will significantly reduce these risks because people will be able to collect water from sources near to their homes. Besides, the project will ensure justice to the victims through an effective online Grievance Redress System (GRS) and close partnership support from legal aid agencies.

Specific selection criteria have been established to remove any discrimination and/or bias. The Grievance Redress Mechanism has further been designed in consideration of the specific local context and draws on existing processes and procedures for the resolution of complaints and grievances in Bangladesh.

9.3 Gender consideration

The project is well aware of gender discrimination in the society of the country. The government adopted a Climate Change and Gender Action Plan (ccGAP) in 2013 to integrate gender issues in all climate change activities. The proposed project will focus on the issue of integrating gender in the project. To address gender issues, the project has developed gender assessment and action plan. However, the project will select 50% women participants. Besides, staffing will consider recruiting sufficient women staff during implementation of the project.

The project will facilitate collaborative learning and development among women and men where women would otherwise face barriers to engagement in decision-making around preparing for and managing climate risks and disasters. The improved abilities of the beneficiaries in accessing or securing community and other resources will further influence gender dynamics at the household and community levels, with ultimate results being that women will be able to claim higher levels of productive assets, human capabilities and protection from shocks. In this way the project contributes to reducing the gender gap of climate change-exacerbated social, economic, and environmental vulnerabilities. Through the livelihoods and capacity building activities for women, girls, and men, the project may also reduce the risks for women to experience violence by enhancing protective factors such as ownership of productive assets, awareness of rights and agency and increased voice in household decision-making for adult women and staying in school for adolescent girls.

The CCAGs will include mostly female members because enhancing capacity of a woman on climate change issues means enhanced capacity of the whole household. The activities are designed in a way that the women will be most benefitted economically and socially. Besides, presence of necessary female staffs will be ensured at the field level so that women members can easily express their opinions and actively take part in the project activities. Allocated budget for female beneficiaries is also very high, which is estimated at more than US$5.56 million.

PKSF will give priority on selecting women headed households in the project activities. The women headed households are those where women are the main earning members and take all types of decisions. The project will also select other women who are not the head of their household rather their husbands are. Because, in many cases, the male heads go out to distant areas for work and they cannot participate in the project activities. PKSF’s practice is to select female beneficiaries rather than male to capacitate and empower the female. Total beneficiaries of PKSF is around 15 million of whom 91% are women.

9.4 Grievance Redress Mechanism

Grievance Redress Mechanism (GRM) will be established at central (PKSF) and IE levels to deal with any complaints/grievances about environmental issues. At the IE level, the Union Parishad (U/P) Chairman or his/her nominated representative from the U/P will be the Local Grievance Redress (LGR) focal point. At the PKSF central level, the Programme Officer (Environment) or any other person/staff nominated by the Project Coordinator of PMU will be Central Grievance Redress (CGR) focal Point. The aggrieved persons or entities will submit the complaints/grievances in sealed envelopes to the selected partner’s office duly entered in the Grievance Register (GR) and will collect a receipt with entry reference to the GR. Partners will not open the envelopes but inform the LGR focal point about receipt of complaints and schedule hearings as per his/her advice. In open meetings, the selected/implementing partner will facilitate the LGR focal Point to hear and discuss the complaints and resolve them in view of the applicable guidelines. The aggrieved person, if female, will be assisted by a female U/P member in hearing, and if from a tribal community, by a tribal representative. LGR focal Point with the help of IE will ensure sending a copy of the complaint via postal mail, email, or other means to the Project Coordinator at the PKSF headquarters.

The IEs will forward the unresolved cases with all proceedings to the Central Grievance Redress(CGR) focal point within 7 days of taking decision by the LGR focal point. Unresolved cases forwarded by IEs will be registered in the office of the CGR focal point and disposed within 15 days. If any decision made by CGR focal point is unacceptable to the aggrieved person/s, he/she/they will forward the complaints with all proceedings to the PKSF Managing Director (MD). The MD will review and resolve the cases, which will be final for PKSF. The MD may seek advice from the PKSF Chairman for any critical issues as per his discretion. A decision agreed by the complainants at any level of hearing will be binding on the concerned IEs and PKSF. The GRM will, however, not pre-empt an aggrieved person's right to seek redress in the courts of law of the land.

The aggrieved persons or entities will have the option to lodge the complaints directly to the Central Grievance Redress (CGR) focal point if they are against the IE, to the PKSF MD if they are against the PKSF project manage mentor directly to the Governing body/chairman of PKSF if there is any issue related to PKSF itself. The institutional arrangement of Grievance Redress Mechanism is illustrated below:

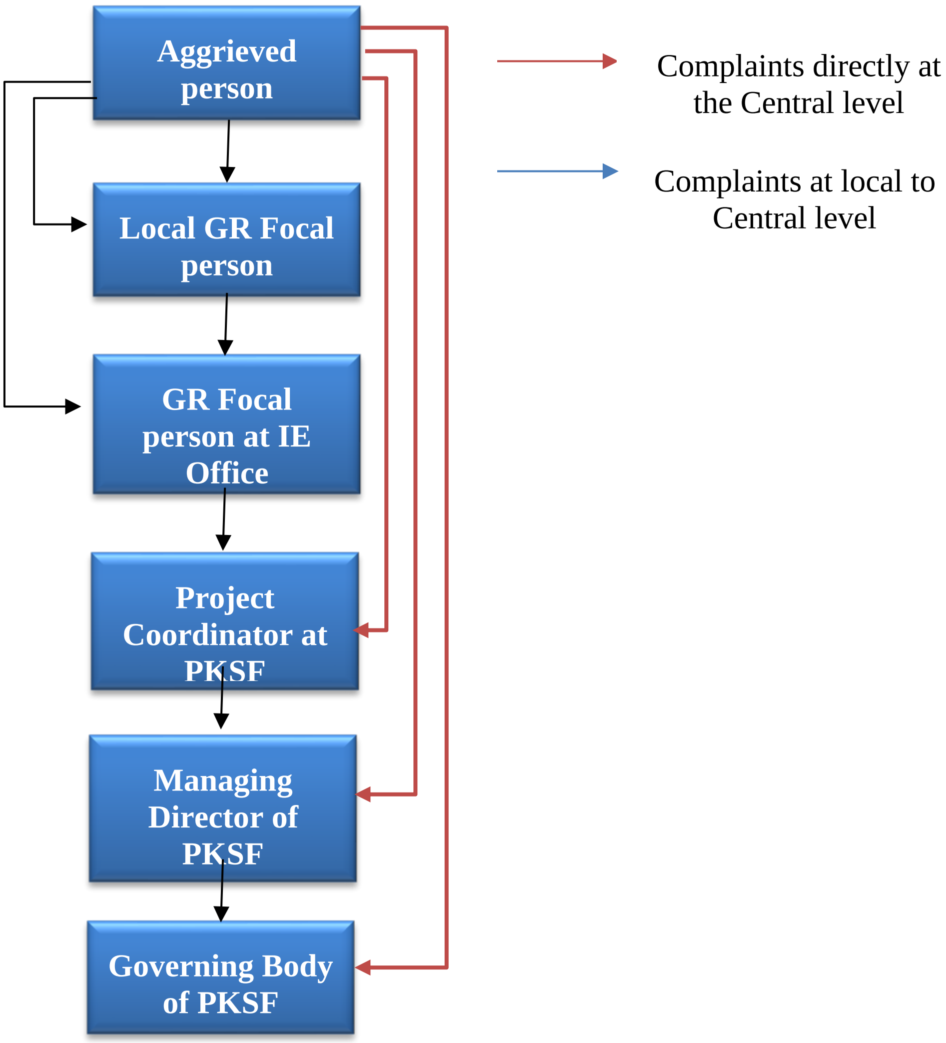

Figure 34: Institutional Arrangement of GRM

10 Conclusion and Recommendation

10.1 Target Population

During 2009-14, 645,381 households in Bangladesh were affected by drought. Highest 25.39% households were in Barind Tract. The total drought vulnerable population are 0.53 million in the targeted district. About 32% of them are poor and extreme poor people. Hence, the project will select only 215,000 beneficiaries for the proposed project. The project will directly improve resilience of these vulnerable people in the selected districts that have high level of water scarcity, food insecurity, and high climatic stress.

Criteria for beneficiary selection

Two sets of criteria for selecting beneficiaries have been considered in the proposed project. The first set of criteria is considered for water related interventions under outcome 2. The selection criteria for beneficiaries include:

- Vulnerability to drought
- Not owning water source, i.e., ponds, tube-wells, dug-wells, etc.
- Having single water source that seasonally dysfunctions due to drought
- Not being involved in any other projects or programmes.
- Priority given to women who collect water for daily household use
- Being poor (as measured by the Poverty Probability Index PPI)

Criteria used to select farmers for drought-adaptive crop cultivation are:

- Being directly involved in farming activities
- Having cultivable land of no less than 1500 square metres
- Being poor, as measured by the Poverty Probability Index

10.2 Climate-resilient technologies

The pre-feasibility study suggests that people and institutions are doing various adaptation measures in addressing climate change, particularly drought. But none of the projects or institutions measured effectiveness and efficiency of those interventions towards increasing resilience. It is clearly established by the feasibility study that there is no established system of measuring effectiveness using appropriate indicators. Lack of capacity of local level institutions and communities in addressing climate change is also evident in the pre-feasibility study. This constrains a transformational shift towards a climate resilient development era. Hence, it is necessary to identify appropriate indicators, measure the effectiveness and efficiency of the interventions and build the informed institutions and communities for addressing climate change at the grassroots level.

The analysis reveals that agriculture-based livelihoods are the most vulnerable groups to climate change and associated disaster. On an average, about 42% households' income source in the selected districts is agriculture and about 30% % is wage labour (BCAS, 2010). These two make a total of about 72% HHs' income source is vulnerable to drought in the selected districts. The project should focus on increasing resilience of agriculture production system as well as livelihood sources through improved technology, training and awareness on climate change issues. The agriculture production system should be supported with supplementary irrigation system, which is environmentally sound and sustainable in nature. Increasing availability of surface water should be the option for supporting the supplementary irrigation.

The study also found that the women are particularly vulnerable to scarcity of drinking water in the drought-prone areas because they are mainly responsible for collecting water for the household. During drought, women have to travel long distances to collect drinking water from tube-wells, dug-wells or deep tube-wells. Because people in the drought-prone areas, do not drink rainwater or water from pond. They only use tube-well water and water from dug-wells for drinking purposes. Hence, suitable options for drinking water is tube-wells and dug-wells. Though this project will not implement dug-well or tube-well for drinking purposes, it will implement MAR system to improve ground water so that the existing tube-wells and dug-wells get water round the year.

Environmental and social impacts of the project are limited as described in Chapter 9. Hence, it does not require carrying out detailed impact assessment study. Environmental and social management framework is developed as part of the project proposal to address these issues.

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