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Water Resources Management for adapting impacts of water scarcity in Barind Area of Bangladesh

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Abstract: *Barind area comprised of Rajshahi, Chapai Nawabganj and Naogaon Districts, is known as the driest part of Bangladesh. Although the area is bounded by Atrai in the north, Mohanada in the west and Ganges in the south, surface water irrigation has not been developed satisfactorily due to its topography and limited availability of surface water in dry season. Groundwater is the main source of irrigation as well as for domestic supply using a large number of Deep (DTW) and Shallow tubewells (STW) both by public and private initiatives. At present there are about 8,955 DTWs and 97,669 STWs (BADC, 2010) in Barind area. In recent years, decline of groundwater table is observed in some areas of the region. Lowering of groundwater table during dry months creates problems in the operation of STW and hand tubewell. In some places of Tanore Upazila,a severe declining trend of groundwater level also observed. In absence of major surface water diversion, added pressure on groundwater will lead to further depletion of the sources. Reduction of surface water flows and lowering of groundwater table combined with climate change will aggravate the existing water scarcity problem. All these have compounded the sustainable management of water in this area. Drought as well as climate change will have pronounced impact on the dry season water availability*

To address these complex problems, it is needed a proper management of surface water and groundwater in an integrated approach. Upazila wise potential resource as well as usable resource, identification of deeper aquifer as well as potentiality, impact of conserving surface water on kharies have been assessed for the study area which is very important for IWRM. Increase use of surface water and optimize use of groundwater for irrigation can minimize the impact of drought and environmental change. Regional cooperation can guarantee a sustainable future in terms of water availability since the basin areas of the river systems is dissected by international boundaries. A strong political commitment supported by adequate institutional arrangement is required in this regard.

Keywords: *IWRM, Drought, Climate Change, Upstream Intervention, Potential Recharge.*

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I. Introduction

Currently, one-third of the world's population is living in countries and regions of water resources limitation (Bates, et al., 2008). Because of limited water availability imposing strong restrictions on natural and human systems, the management of water resources has become an increasingly imperative issue in semiarid and arid regions. Generally, when the demand of water has reached the limits that the natural system can provide, water shortage can become a major obstacle to social and economic development for one region (Bronster et al., 2000; Li et al., 2006). Therefore, these issues have forced planners to contemplate and propose ever more comprehensive, complex, and ambitious plans for water resources systems in the semiarid and arid regions (Li et al.,2008).

Different studies have documented that groundwater level declined substantially during the last decade causing threat to the sustainability of water use for irrigation in this region and impacting upon other sectors too (Jahan et al. 2010). Due to lack of proper knowledge, indiscriminate installation of pumps and non-availability of modern technologies, farmers inappropriately lift water without caring ground sources. These impacts upon interlinked sources of water table which is declining alarmingly in many areas of Bangladesh. Although the groundwater dominates the total irrigated area, its sustainability is at risk in terms of quantity in the northwest region (Simonovic 1997; Shahid 2011). Frequent shortage of water in the region has had impacts that can be ranged as economical, social and environmental (Takara and Ikebuchi, 1997; Sajjan et al. 2002; Dey et al. 2011).

A recent study shows that groundwater level in some areas falls between 5-10 m in dry season and most of the tubewells fail to lift sufficient water (Dey and Ali 2010). Researchers and policymakers are advocating sustainable development as the best approach to today's and future water problems (Loucks2000; Cai X et al. 2001). With groundwater development, fluctuations will amplify; but as long as rainfall is managed to recharge aquifers, and proactive water saving strategies are put in place, a steady and sustainable state can be achieved (IWMI 2010). In mainstream irrigation thinking, groundwater recharge is considered as a by-product of flow irrigation, but in today's world, groundwater recharge needs to be understood on its first emergency for making groundwater sustainable integrating all possible options (IWMI 2010).

Hydrologic model was a useful tool for water resources management (Sahoo et al., 2006). Previously, many lumped hydrologic models were developed to investigate watershed hydrology. With a low data requirement, these lumped catchment models could reflect runoff dynamics and water balance in water resource management systems. However, the lumped models assumed the study watershed as a spatially homogeneous region, and the spatial heterogeneity of the climate variable and land surface was not considered (Bronster et al., 2000).

Consequently, several distributed and semidistributed hydrological models were developed in response to the aforementioned challenges (Apul et al., 2005). For example, Refsgaard (1997) integrated MIKE SHE, MIKE 11, MIKE 21, and DAISY to study the environmental assessment in connection with the Gabcikovo hydropower scheme. Sahoo et al. (2006) used the physically distributed hydrological modeling system (MIKE SHE) to study the watershed response to storm events within the Manoa-Palolo stream system on the island of Oahu, Hawaii. IWM (2005, 2006, 2009 and 2014) used the physically distributed hydrological modeling system (MIKE SHE & MIKE 11) for the assessment of potential groundwater and surface water resources. The primary advantage of the distributed hydrological models was enabled to reflect the spatial variations for characteristics of watershed (e.g., rainfall, topography, soil type, and land use) (Refsgaard, 1997). However, higher data requirement became a main obstacle on extensively applying these models to practical problems.

Both the Poverty Reduction Strategy (PRS) and Millennium Development Goal (MDG) of the Government of Bangladesh attached priority to increase agricultural production. In this backdrop, Barind Multipurpose Development Authority (BMDA) undertook a programme entitled "Groundwater Resource Study for Barind Integrated Area Development Project, Phase-III". The study area is shown in Fig. 1 where yearly rainfall varies from 1250 mm to 2080 mm and land level varies from 9 to 47 mPWD. The main objective of the study was to explore groundwater potential below 80.0 m in resource constraint and high Barind areas in Rajshahi, Chapai Nawabganj and Naogaon districts to bring more area under irrigation using mathematical modelling techniques.

The objective of this paper is to review the state of art for investigation of potential groundwater resources for irrigation and ultimately water resources management in high barind area.

II. Approach and Methodology

Estimation of groundwater potential for a region is essential not only for sustainability of irrigation project but also for a sustainable water resources management at the regional level, which means in general at the basin scale. Due to the competition of all water users of a river basin, especially in water scarce regions, a comprehensive approach is needed regarding agricultural, domestic, industrial, and ecological aspects.

In order to achieve the study objectives, IWM (2006, 2012) developed an integrated GW-SW model for the study area. The models developed under this study based on MIKE-11 (DHI, 1999) and MIKE-SHE (DHI, 1999). All the major river systems and updated topographic features were included in surface water (sw) model setup while hydro-geological setting, aquifer properties, DEM, land use pattern, abstractions were incorporated in groundwater (gw) model. Both the models were coupled through MIKE SHE. The calibrated model was used to simulate various options and to assess the resources.

For sustainable management of scarce water resources and to mitigate the impact of drought, integrated water resources management (IWRM) is needed applying technically based procedures to assess the hydrologic and environmental consequences of different water resource management strategies. An attempt has been made in this paper to evaluate the existing condition of groundwater and to assess the possible effects and impacts of drought on groundwater in Barind area with focus on appropriate technologies for assessing hydrologic and environmental consequences of IWRM. Effective management strategy of groundwater resources under complex situation also has been tried to illuminate in this paper.

Potential recharge was assessed upto the depth which recharge fully during monsoon due to rain. Usable recharge was considered as 75% of the potential recharge (IWM, 2006) to account for various uncertainties inherent in different assumptions and natural loss. Irrigation zones were demarcated on the basis of water availability, groundwater level fluctuation, functionality of suction mode pumps, safe yield, extent of irrigation coverage, extent of drainage congestion etc. Environmental impacts, social acceptance and economic viability of the project were also assessed.

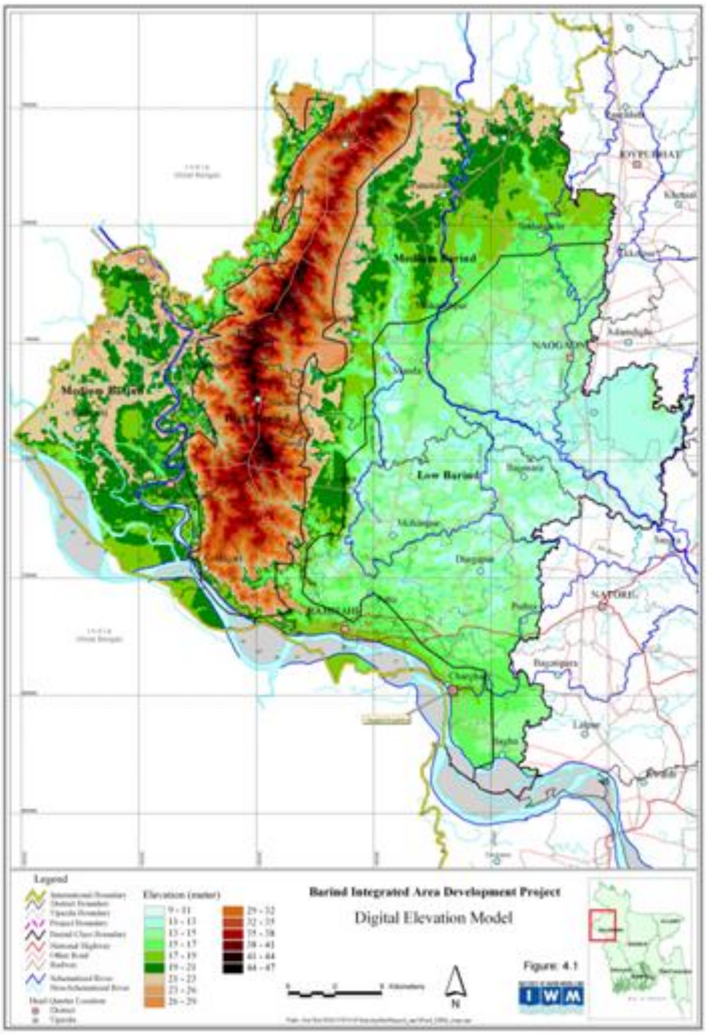

Figure 1: Location Map of the Study Area

III. Results and Discussions

3.1 Impact of Drought

Drought may have a serious impact our environment, economics and society. The impact of drought on environment is the result of damages to agriculture crops, plants and animal species, air and water quality, forest and fisheries, degradation of landscape quality, loss of biodiversity and soil erosion. The economical impact occurs in agriculture and related sectors, including forestry and fisheries, which depend on the surface and groundwater supplies. In addition to losses in yield in both crop and livestock production, drought is associated with the increase in insect infestation, plant disease and wind induced erosion. During extreme drought need of water for livestock and human consumption create prime necessity as social demand. In these cases, some emergency sources of water are required to take safety measure to safe guard public health.

3.2 Rational for Groundwater Use

Though surface water is available at near the outfall of the Mohananda river into the Ganges and in the Ganges River, large pumping plants are required for pumping from the river. Moreover, the water levels of the rivers in some reaches go down beyond the suction limit of low lift pumps becoming the problems of pumping from river. Due to undulated topography, the study area is not suitable for flood irrigation. However, pumping from the rivers and conserving water by small water control structures are being practiced for limited surface water irrigation. Main dependence for irrigation is on ground water. Groundwater is being extracted for irrigation mainly by deep and shallow tubewells. There are about 8,955 DTW and 97,669 STW in Barind area (BDAC, 2010). The irrigation coverage by each DTW is in the range of 12 ha-25 ha, the average is being 23.68 ha per DTW. Irrigation coverage by each STW is in the range of 1.0 ha-5.0 ha. The average is 2.42 ha per STW and the average coverage per LLP of 1 cfs capacity is 5.63 ha.

After development of groundwater, irrigation coverage and agricultural yield in the area has significantly been increased as well as the cropping pattern has also been changed. Now a days Rabi cultivation season is also known as main irrigation season. However, impact of groundwater use has not been well monitored.

1.1 Policy Statement for Groundwater Use

The government policies that have direct relevance with use of groundwater are mainly the National Water Policy (NWPo) and National Agricultural Policy (NAP). In the context of water use, the objectives of the NWPo are to promote agricultural growth through private development of groundwater along with surface water development, where feasible. The main elements of Government policy for use of water are to (i) encourage and promote continued development of minor irrigation without affecting drinking water supplies, (ii) encourage future groundwater development for irrigation by both the public and the private sectors, (iii) improve resource utilization through conjunctive use of all forms of surface water and groundwater for irrigation, (iv) strengthen systems for monitoring water use, water quality and groundwater recharge. (v) strengthen crop diversification programmes for efficient water utilisation, (vi) develop and promote water management techniques to prevent wastage and generate efficiency of water and energy use and (vii) produce skilled professionals for water management.

Recently Government has approved the Poverty Reduction Strategic Paper (PRSP) that provides the guideline to achieve the Millennium Development Goals (MDG). In the PRSP, among others, due emphasis has also been given on the rational and productive utilization of the water resources. The main elements of the PRSP as stated in Policy Matrix which have relevance with the efficient and productive use of water includes, among others (i) create additional irrigation facilities utilizing surface water resource where justified, (ii) ensure conjunctive use of surface and groundwater in existing Command Area Development Projects, (iii) monitor quality and quantity of groundwater on regular basis, (iv) augment surface water in rivers, creeks and khals by constructing barrage, rubber dam and water control structures and (v) promote community participation in multipurpose use of water.

1.2 Water Resources in Barind Area

Considering lithological variations and groundwater flow capacity, hydro-stratigraphic units of the study area have been defined as Clay Top, Upper Aquifer, Clay Middle, Lower Aquifer and Clay Bottom (Figure 2). Accordingly, up to the studied depth (~80 m), total 5 hydro-stratigraphic units have been demarcated. It reveals from the hydro-stratigraphic analysis that within the studied depth upper aquifer and lower aquifer is interconnected. Clay middle is not continuous layer. In fact, there is only one aquifer in the study area. The main aquifer, in most of the area, is either semi-confined and leaky or consists of stratified, interconnected, unconfined water-bearing zones which are subject to delayed drainage. Recharge to the aquifer is predominantly derived from deep percolation of rain and flood water. Lateral contribution from rivers comprise only a small percentage 0.04% (MPO, 1987) of total potential recharge.

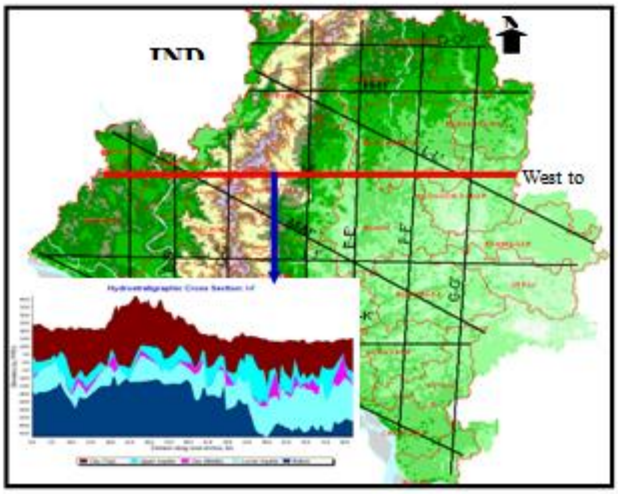

Figure 2: Sample Plot Hydro-Stratigraphic Cross Section

Analysis reveals that in high barind area, specific yield varies from 0.01 to 0.06, while in low barind area, it varies from 0.06 to 0.30. Low specific yield will cause excessive draw-down in tubewell, if high abstraction rates are used. In high Barind area, hydraulic conductivity varies from 10 m/day and 20 m/day whereas in low barind area it varies from 40 m/day to 70 m/day. In high barind area, transmissivity is lower than

1000 m2/day whereas in low barind area it is higher than 1000 m2/day. Highly transmissive aquifer material indicates excellent opportunity for sustainable groundwater development in the area.

Hydrographs of observed groundwater tables show that the maximum and minimum depth to groundwater table occurs at the end of April and end of October respectively. In some places of the areas, depth to groundwater table goes below 7.0 to 25.0 m. Suction mode tubewells do not operate in the areas. However, during the peak time of recharge, groundwater table almost regains to its original positions except some places of Tanore. It can be seen from Figure 3 that groundwater is declining at some places of Tanore. In these areas, recharge is less compared to the total abstractions. Decline of groundwater table is mainly occurred due to higher abstraction round the year. In order to avoid this alarming situation groundwater abstraction should be controlled in that area.

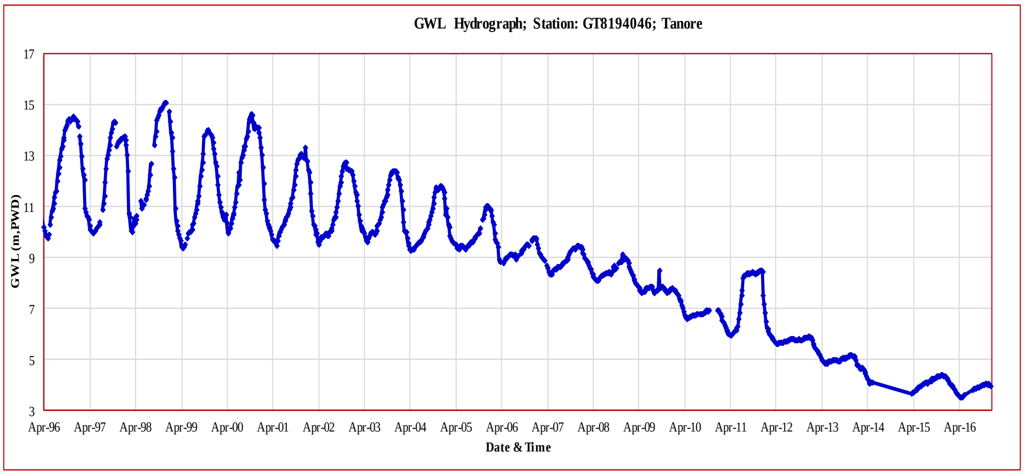

Figure 3: Declining Groundwater Trend in Tanore

Installation of Deep tubewell in Barind area is a notable irrigation project in this area. Besides these, private initiatives have also flourished and now playing a significant role in irrigation development. Groundwater use for agricultural production has significantly been increased over the time. The other areas where groundwater is widely used are the domestic and drinking purposes. Contribution of groundwater for domestic water supply in rural and urban towns in northwest region is about 97%. The remaining use of water is from river and pond. The groundwater being used for domestic purpose is considered to be safe except the detection of Arsenic in Chapai Nawabganj district in recent years. The wide spread use of groundwater for drinking purpose has resulted in significant reduction in water borne diseases like cholera, diarrhoea, dysentery, typhoid etc.

The current water management plans are mostly based on existing knowledge and sparsely aims at optimum use of precious resources. An improved understanding of the hydrologic processes that determine the resource and movement of water in this region is critical to the development of effective strategies for sustainable development water management. The management strategy of groundwater resources depends on the following aspects:

- Assessment of availability of water resources;
- Understanding the recharge mechanism;
- Assessment of total water requirements;
- Identification of scope for future irrigation expansion based on water availability;
- Development of Groundwater Monitoring System;
- Estimation required number of Deep Tubewell;
- Determination of proper spacing between two tubewells, DTWs in particular;

Barind Multipurpose Development Authority (BMDA) realized the need for analyzing the consequence of groundwater development to ensure long term sustainability. Accordingly, groundwater model study was carried out for optimum utilization of available water resources. As a result, an integrated MIKE 11-MIKE SHE modelling system has been adopted in this study. In the present study, all the major rivers and khals within the study were coupled with groundwater. Type of river-aquifer exchange and the flooding condition have also been defined. The exchange of flow between the saturated zone component and the river component is mainly dependent on head difference between river and aquifer and properties of riverbed material such as leakage coefficient. For river-aquifer exchange, leakage coefficients along with the hydraulic conductivity of the saturated zone are taken into account for most of the river reaches. For the study area, the Upazila wise estimated potential recharge, usable recharge which is 75% of potential recharge, abstraction and remaining water is given in Table 1 (IWM, 2012).

Table 1: Upazilawise Potential Groundwater Resources and Total Demand

Thana	Area (km^2)	Potential Recharge in mm	Thana	Area (km^2)	Potential Recharge in mm
Atrai	284	725	Nachole	284	496
Badalgachi	214	677	Naogaon	276	648
Bagha	184	464	Nawabganj	452	710
Bagmara	363	527	Niamatpur	449	451
Bholahat	124	564	Paba	280	502
Charghat	165	452	Patnitala	382	390
Dhamoirhat	301	531	Porsha	253	358
Durgapur	195	425	Puthia	193	545
Godagari	472	521	Raninagar	258	585
Gomostapur	318	413	Sapahar	245	411
Mohadevpur	398	444	Shibganj	525	561
Manda	376	618	Tanore	295	357
Mohonpur	163	407			

Potential Resources in Deeper Aquifer

The deeper aquifer available in the high barind area is semi-confined in nature. Though the available thickness of the aquifer in some places is quite sufficient, the quality of the aquifer is not so good because the specific storage and the conductivity of the aquifer available from the result analysis of the aquifer test are not so good. This is why the deeper aquifer is not so rich. Though the potential resource for semi-confined aquifer is not applicable, through model simulation, the resource potential for deeper aquifer has been performed to investigate the opportunity for groundwater development using deeper aquifer in this area. It has been estimated that there are opportunity for installation of total 3 numbers DTW in deeper aquifer at Saidpur area without any negative environmental degradation. Though further detail investigation for deeper aquifer was recommended as there were a lot of limitations in the developed model addressing deeper aquifer due to shortage of different kinds of data used.

1.3 Surface Water Availability

For the purpose of assessing surface water resources, discharge data were analyzed to estimate the flow event for different return periods. Table 3, shows the dry period 80% dependable flow in different rivers of the study area. It is observed from Table 3 that some water resources are available in Atrai and Mohananda while very limited resource is available in Sib-Barnai river.

Monthly available resources in the above rivers also have been analyzed. Conservation of these resources have been considered by construction of rubber dam. For sustainability of river, it is not feasible to conserve or utilize all available resources. As such, useable resource has been considered as 70% of the available resources and 30% of the available resources have been taken into account as “in-stream flow requirement” in the river.

Table 1: River Flow in Dry Period

River	80% Dependable Flows (m^3/s)					
	Nov	Dec	Jan	Feb	Mar	Apr
Atrai River						
1. Ch. 4.840 km at Mohadebpur	10.72	7.35	5.52	3.4	1.95	0.92
2. Ch. 54.290 km at Atrai R. B	17.61	10.62	6.62	4.17	2.12	1.32
Sib-barnai River						
1. Ch. 54.290 km at Pearpur	3.27	0.29	0.26	-	-	-
Mohananda River						
1. Ch. 49.450 km at Nawabganj	79.58	52.35	38.29	14.41	6.76	5.42

1.4 Impact of Environmental Change on Groundwater

Environmental change compounds the challenges of sustainable groundwater management of this area as it has significant impact on groundwater levels and recharge capacity as well as water demand. Following issues related to global environmental change and its impact on groundwater resources have been discussed below;

Climate Change

Climate change is strongly affecting many aspects of physical and biological systems, particularly rainfall distributions and increases of temperature. In Bangladesh, recent studies indicate that there is an increasing trend of temperature of about 10 C in May and 0.50 C in November during the 14 year period from 1985 to 1998 (Mirza, 2002). Decadal rainfall analysis on long term averages since 1960 also indicate anomalies. The temperature projection for the 21st century based on climatic models indicate that in South Asia annual mean warming would be about 2.5 0 C (IPCC, 2007).

Intensified use of groundwater can minimize the effect to some extent. The combination of shorter duration but more intense rainfall (meaning more runoff and less infiltration) combined with increased evapotranspiration and increased groundwater abstraction will lead to further groundwater depletion in this area.

Land use change

Land use and land cover change due to increasing population and urbanization is one of the largest mechanisms of global change. Unprecedented global land conversion continues to occur with increasing needs for food, fiber, and homes. Due to rapid urbanization and increasing population, forest and agricultural areas are being reduced world wide. In addition, industrial areas also have been increased. In consequent of this, release of carbon dioxide is being increased, which increases temperature that has significant impact on the transpiration and water-use efficiency of vegetation.

In northwest region of Bangladesh, growth of cities and rural settlement has been increased rapidly due to development of infrastructures. Consequently, land available for forest and agriculture has been reduced. It is expected that further development of infrastructures will reduce the area of land available for forest and agriculture by some 17 % (NWMP, 2001) over the next 25 years. This land use change will reduce groundwater recharge area leading to groundwater depletion.

1.5 Necessary Steps for Future Action

Indiscriminate use of groundwater has already caused some local water scarcity problems in this area. Occurring of drought and environment change will aggravate the water scarcity problems in future. There should have a balance between groundwater recharge and withdrawal. Accordingly, judicious use of surface and groundwater in an integrated water resources management approach is equally important to mitigate the impact of drought in the study area. In this regard, following measures need to be taken i) Use of surface water by constructing diversion structure on major river ii) harvesting of rainfall iii) introduce alternate wet and dry (AWD) method for irrigation to reduce irrigation demand. iv) crop divercification with less water consuming crops v) supplementary irrigation in wet season by surface water vi) Monitoring of groundwater both in quality and quantity vi) implementation of North-Rajshahi Irrigation project by improving the condition through construction of Ganges Barrage and vii) Regional Cooperation

It has been observed from a model study (IWM, 2006) that sufficient rainwater in kharies can be conserved by retention structures. Supplementary irrigation is possible using this water. In addition, groundwater recharge also increases by conserving rainwater in kharies. In view of that, Sarmongla khal (Figure 4) is being used for conserving rain and surface water. However, it is suggested to utilize all kharies in Barind area for conserving rainwater. A feasibility study for conserving rainwater in kharies, depression and low lying areas, Atrai, Mohananda, Sib-Barnai and Little Jamuna river for suppmentary irrigation of T.aman should be taken up

Figure 4: Sarbomongla Khal for conserving rain & surface water

IV. Conclusions

Earlier Barind area was drought prone area and symptoms of desertification were found due to shortage of surface water and rainfall. After development of groundwater for irrigation, crops are grown almost everywhere and farming practices have strongly influenced the present vegetation. However, impact of groundwater use should be monitored and it should be used judicially without creating environmental hazards. In Barind area, the problems that are being faced related to water availability, use, control and management are not new. These problems have been aggravated in recent years and will continue in future due to global environment change. In this regard, conjunctive use of surface and groundwater, development of a monitoring system and finally regional cooperation is essential. For sustainable development of Barind area and to mitigate the impact of drought, the following recommendations may be prescribed:

- Rainwater harvesting through construction of cross dam on different Kharies in Barind area
- Introduce less water consuming crops through crop diversification
- Introduce of alternate wet and dry (AWD) method for irrigation to reduce water consumption
- Promote surface water irrigation where and when possible
- Introduce artificial recharge by installation of recharge well

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