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Rainwater harvesting: a means of ensuring groundwater resources of the Barind, NW Bangladesh

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ABSTRACT

The present study focuses on rainwater harvesting for irrigation and homestead purposes. The undulatory Barind Tract (Pleistocene terrace) covers about 7,250 sq. km and is underlain by thick clay-rich palaeosol sequences. Groundwater of this region is used as the only resource to meet the increasing irrigation demand for production of food to nourish over a million people. Thick clay beds at the top of aquifer and discontinuous subsurface proximal recharge areas have significantly reduced both vertical and lateral recharge potential. Groundwater domain of the Barind Tract has also reached a critical state due to low rainfall, scarcity of surface water sources, and unplanned tapping of groundwater by ever-increasing number of tube wells. As a result, overdraft of groundwater is quite evident. The present situation apparently poses a serious threat to the ecosystem of the study area.

To stop further deterioration of groundwater development in the Barind Tract, a rainwater harvesting technique was tested by excavation of ponds at on-farm level. Results of a three-year long experiment demonstrated that an appropriate and timely intervention helps the community to overcome the problem of increasingly acute water shortage. The present study revealed that the rainwater harvesting is very cost-effective and may prevent a potential economic and social disaster of the Barind Tract.

INTRODUCTION

The Barind Tract is situated in the northwestern part of Bangladesh (Fig. 1). This region seems to have become the worst victim of unplanned tapping of groundwater by ever-increasing number of tube wells both by the government and public sectors. Groundwater of the Barind region is used as the only resource to meet the increased demand for production of more food to nourish over a million people. The unscientific application of high yielding variety (HYV) crop technology of the green revolution without weighing up the environmental ramifications seems to be the major factor responsible for the deterioration of the groundwater resources. These unplanned and unscientific interventions in the agricultural sector of the region seem to have produced definite changes in land cover, soil fertility, and soil moisture to the extent of micro-level desertification (Khan et al. 1985).

A successful water management of any area requires a conjunctive use of both surface and subsurface waters. It is unfortunate that the use of surface water was totally ignored during so-called green revolution. Though the revolution induced a temporary boost in production, now it has been proved unsustainable, as it posses a serious threat to the ecosystem of the Barind Tract. It is reported that during the time of late eighteenth century, there were more than 70,000 ponds of different sizes in the Barind region. These were excavated by the prudent *Zamindar* (Landlords) of the past to fulfil the homesteads and supplementary irrigation requirements. In the middle of the twentieth century, three-quarters of those ponds were choked and ultimately transformed to a cultivable land to keep pace with the green revolution. The idea of present research was actually developed from the work of those wise men of the past. Consequently, an attempt has been made to excavate the mini ponds more scientifically for harvesting rainwater and to use that water for irrigation to stop further deterioration of groundwater in the Barind Tract.

SETTING AND NATURAL ENVIRONMENT

The Barind Tract is one of the major geomorphological units of the Bengal Basin (Fig. 1). It is located between latitudes 24° 20' – 25° 30' N and longitudes 88° 10' – 89° E, and covers approximately 7,250 sq. km. The area is made up of Quaternary deposits. Apart from the Older Ganges alluvium deposits, a large part (three-quarters) of the tract belongs to the Pleistocene deposits of thick clay. This clay is also designated as the Barind Clay (Monsur and Paepe 1992), because of its distinctly different nature of deposition. The Barind Tract is slightly elevated (20–45 m above mean sea level) and undulatory due to the presence of horsts and grabens at the basement (Khan 1991; Khan and Rahman 1992). This area is also criss-crossed by several en échelon basement faults (Khan and Choughan 1996). Such anomalous situation in the subsurface has also played a critical role for the movement of groundwater in the region (Khan and Sattar 1994a). Physiographically, the study area can be divided into i) the Central Barind Tract, which has

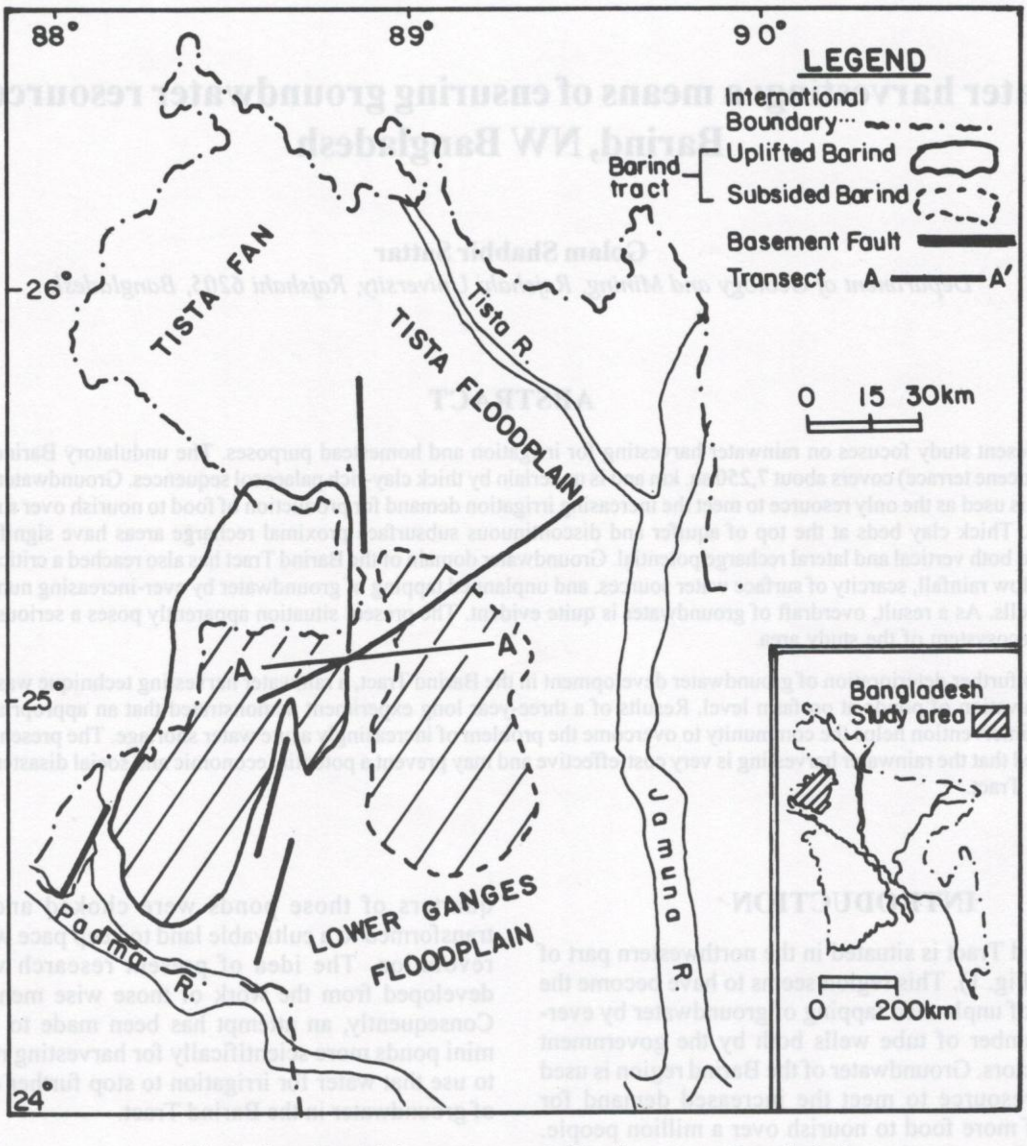

Fig. 1: Location of the study area in Northwestern Bangladesh

the highest relief and slopes downward both to the east and west (BWDB 1989); ii) small portion of Western Barind; and iii) the older Ganges floodplain between the Eastern and Central Barind.

The climate of the study area is typically humid and tropical with three characteristics seasons: winter, pre-monsoon, and monsoon. Temperature and rainfall regimes are distinctly seasonal. The mean temperature of winter is 16° C whereas that of summer is 35° C. It receives a mean annual rainfall just over 1,250 mm, which is less than the average rainfall (2,500–4,000 mm) of the country (Huq and Rahman 1994). Nearly 90 % of the total rain falls between June and October (monsoon). Normally, the central Barind is totally free from floods.

Most of the soils of the Barind region are acidic (pH=4.8–6) and less fertile. The average organic matter content of the soil varies between 0.8 and 1.2 %, and is also indicative of the poor structure of the soil. During *Kharip-1* (summertime cultivation), only 5–15 % of the total cultivable land is capable of producing *Aush* rice due to the lack of soil moisture. The production rate of this rice is very minimal and varies from 0.5–1.5 tons/hectare. After the end of *Kharip-2* (rain-fed season), due to insufficient soil moisture in the tree-root zone, the possibilities of planting winter crops are also limited.

PRESENT GROUNDWATER STATUS

The study area consists mostly of the Pleistocene alluvium. The whole succession of these deposits represents a number of palaeosol horizons (Alam 1998). The exposed thick surface (10–45 m) of the Barind Clay (Fig. 2) comprises deep reddish brown (7.5 YR 4/6) to brownish yellow (10YR 6/8), highly oxidised and weathered clay, silty clay, and very fine sand with ferruginous concretions and calcareous nodules. Because of the thick clay, the infiltration

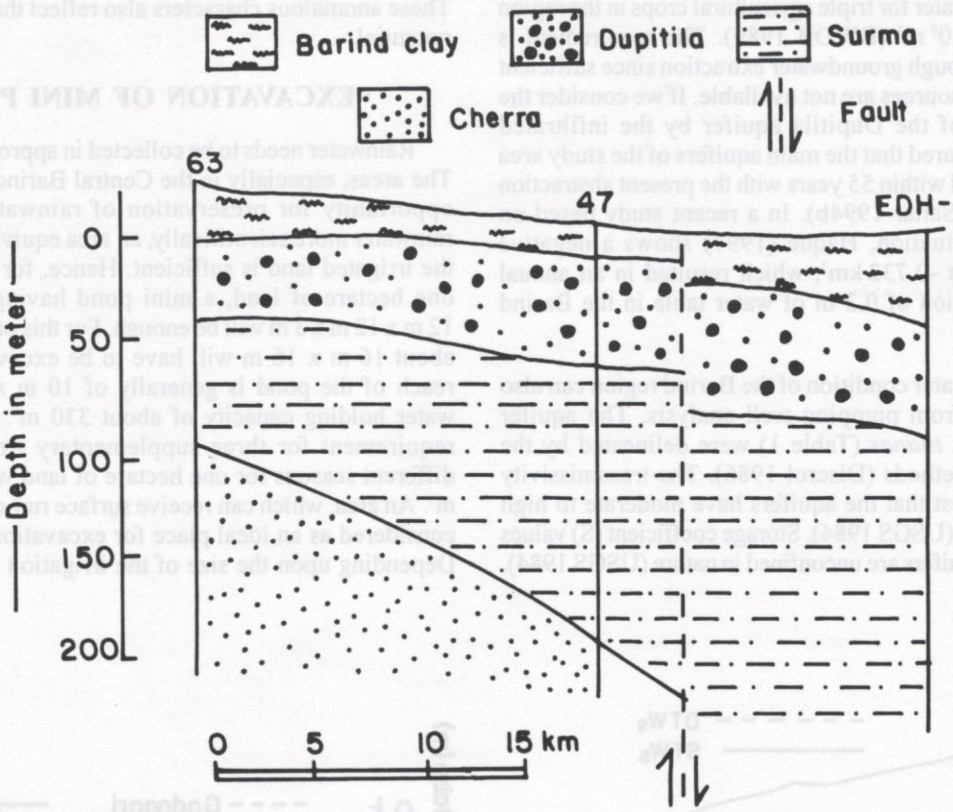

Fig. 2: Geological cross-section along AA' showing the aquifer disposition

rate is very low and varies from 0.1 to 0.03 cm/h (Shamim 1999). The geological cross-section (Fig. 2) based on the drilling report of BWDB (1989) reveals that there are two types of aquifer in the study area. Those are shallow aquifer (with the depth ranging from 30 to 40 m) and deeper aquifer (45 to 90 m). Most of the shallow tube wells (STWs) extract water from the Dupitila Formation (Khan and Muminullah 1989) under water table conditions, while the deep tube wells (DTWs) with drown water mostly form the Dupitila or the Surma Formation (Khan and Muminullah 1989). The deeper aquifers are either leaky unconfined or confined in nature. Fig. 2 shows that the main groundwater-bearing formation i.e., the Dupitila has truncated against both the Barind Clay and Surma Formation. This anomalous situation creates a disruption in the continuity of subsurface stratum and significantly reduces the lateral recharge potential.

Number of water wells

The increased density of both shallow and deep wells for tapping groundwater has cumulatively produced negative impacts on groundwater and is leading to rapid water table depletion. Installations of STWs and DTWs began in the Barind region during mid-seventies. Considering the situation of Manda Than, a region of the Barind, during 1976 there were only 10 DTWs (BMDA 1995), but in 1995 their number reached to 341 (Fig. 3). On the other hand, the increasing number of STWs is also alarming. In 1976 it was around 35, but in 1995 it reached to more than 2144 (Fig. 3). These indiscriminate installations have an adverse impact on the water table of the Manda area. Fig. 3 shows that the pre-monsoon depth of water table is directly related to the number of water wells: as the number of wells increased, the depth to water table also increased accordingly. At present, more than 4,000 DTWs and 22,000 STWs are in operation in the Barind Tract.

Water table

The overexploitation of groundwater is well documented by the decreasing trends of water table in different areas of the Barind (Fig. 4). The pre-monsoon depth to water varies from 2 to 5 m below ground level (BMDA 1995). Fig. 4 shows a general declining trend of water table in the study area over a period of 30 years (between 1965 and 1995).

Groundwater recharge and discharge

The main aquifer of the Barind area is the Dupitila Formation, which comprises unconsolidated sand with occasional pebbles. Considering the average porosity of 25% and the average thickness of 50 m of the Dupitila Formation, the total volumetric capacity of aquifer to hold the water is about 3.2 x 10^{10} m^3 in saturated condition. The average infiltration capacity of the region is about 13 % (Depperman and Theile 1973). The possibility of volumetric recharge from rainfalls is about 6 x 10^8 m^3. The total annual requirement of water for triple agricultural crops in the region is about 1.2 x 10^9 m^3 (BWDB 1989). The requirement is fulfilled only through groundwater extraction since sufficient surface water resources are not available. If we consider the replenishment of the Dupitila aquifer by the infiltrated rainwater, it is feared that the main aquifers of the study area will be exhausted within 55 years with the present abstraction rate (Khan and Sattar 1994b). In a recent study based on water table fluctuation, Haque (1997) shows a negative balance of about -0.732 km^3, which resulted in an annual average declination of 0.3 m of water table in the Barind region.

The groundwater condition of the Barind region can also be ascertained from pumping well analysis. The aquifer properties of six *thanas* (Table 1) were delineated by the Cooper-Jacob methods (Discrol 1986). The transmissivity (T) values suggest that the aquifers have moderate to high yielding capacity (USGS 1984). Storage coefficient (S) values reveal that the aquifers are unconfined in nature (USGS 1984). These anomalous characters also reflect their poor recharge potential.

EXCAVATION OF MINI PONDS

Rainwater needs to be collected in appropriate reservoirs. The areas, especially in the Central Barind, offer an ample opportunity for preservation of rainwater. To hold the rainwater more scientifically, an area equivalent to 1/40th of the irrigated land is sufficient. Hence, for the irrigation of one hectare of land, a mini pond having dimensions of 12 m x 12 m x 3 m will be enough. For this purpose, an area of about 16 m x 16 m will have to be excavated. The lower reach of the pond is generally of 10 m x 10 m with the water holding capacity of about 330 m^3. The total water requirement for three supplementary irrigations in two different seasons for one hectare of land will be about 210 m^3. An area, which can receive surface run-off easily, is to be considered as an ideal place for excavation of mini ponds. Depending upon the size of the irrigation land, the size of

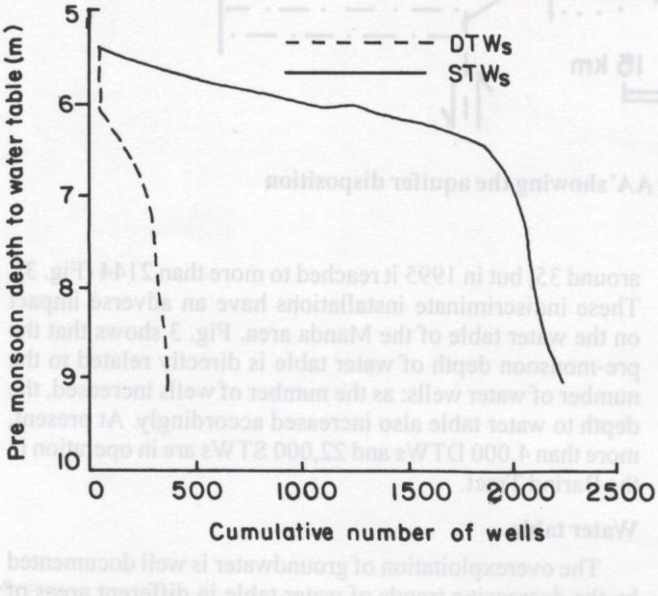

Fig. 3: Relationship between trend of water table and number of wells (DTWs and STWs) at Manda

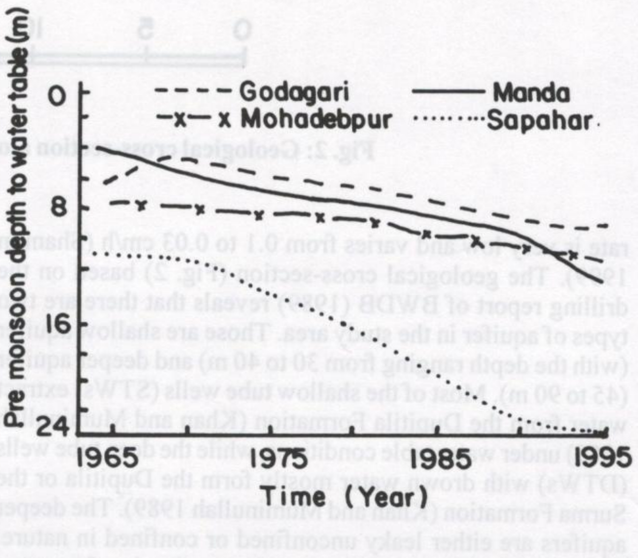

Fig. 4: Declining trend of water table at various locations

Table 1: Aquifer test analysis of seven *thanas* of Barind Tract (test operation in 4320 minutes)

Location	Discharge (l/s)	SWL from ground surface (m)	Permeability k (m/day)	Transmissivity T (m^2/day)	Storage coefficient S
Tanore	30	9.35	40	700	0.05
Godagari	34	6.88	15.18	600	0.10
Gomastapur	30	6.32	17	300	0.04
Shibganj	36	9.40	14	400	0.05
Nachole	34	11.60	12	224	0.06

the mini pond can also be adjusted, but it is advisable to keep the depth of 3 m.

Results of on-farm experiments

Between 1994 and 1995, eight mini ponds were excavated at Godagari Thana of the Barind region. More than twenty trees were planted and some winter vegetables were grown on the banks of each pond. The average results of the three-year long experiments with these ponds are presented in Tables 2 and 3. It was observed that just after applying two supplementary irrigations, the production of both native rice (*Aman*) and HYV rice (Mukta, BR-11) increased significantly. The increased rate of production was 51 and 76 %, respectively(Table 2A). In terms of economic return, a farmer having one hectare of land could earn US$ 162 and 240, respectively by applying this supplementary irrigation from the pond water (Table 2B). Considering the excavation cost, irrigation cost, and the value of the irrigated land (Table 3), the net return was US$ 47 and 131, respectively only within three months.

Table 2: Benefit due to supplementary irrigation. Rice variety: AMAN (February-mid May)

A. Crop (Ton/hectare)	**Ragushail (Native)**	**Mukta (BR-11) (HYV)**
Production without irrigation	2.38	2.9
Production due to supplementary irrigation	3	5.1
Excess production due to supplementary irrigation	1.24	2.2
Production increase (%)	51	76
B. Return ($) per hectare		
Production without irrigation	312	322
Production due to supplementary irrigation	468	554
Excess production due to supplementary irrigation	162	240

Table 3: Cost-benefit for excavation and irrigation from proposed mini ponds. Rice variety: AMAN (February-mid May)

Expenditure ($)	**Aman (Native)**	**Mukta (BR-11) (HYV)**
Excavation cost	90	90
Irrigation cost (per hectare)	5	5
Value of excavated land	8	8
Profit ($)		
Excesses profit	160	244
Net profit	47	131

CONCLUSIONS

The ecosystem of Barind region is rapidly deteriorating. To get rid of this alarming situation, groundwater extraction has to be stopped or at least reduced immediately. Importance has to be given on the conjunctive use of subsurface and surface waters, and the schemes for excavation of mini pond have to implement immediately.

There are many advantages of excavating mini ponds:

a) no ownership problem for water, as even a poor farmer can afford to excavate about 1/40th of his cultivable land;
b) excess water can be sold to others;
c) there will be an increase in production from 51 to 76%;
d) supplementary vegetables can be grown on the banks of the pond and it will help to solve nutritional problems;
e) tress on the pond banks can be sold within 12–15 years;
f) cost of the excavated land will be covered within one year, and in the next year the profit will be doubled; and moreover
g) the net profit will be US$ 47–131 in three months. The proposed rainwater harvesting technique has already been proven to be very useful. It can also restore the damaged ecosystem of the region in time.

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