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Solar Powered Dug Well Irrigation with Rain Water Harvesting System to Reduce Ground Water Overdraft at Joypurhat District in Bangladesh.

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Abstract

Dug Well irrigation is now very popular adoption to change the traditional agriculture practice in north-west region of Bangladesh. Due to consecutive several years of drought, depletion of ground water, shortage of rainfall, dryness of surface water bodies, increasing crisis of food production with respect to population growth is worsening the food crisis day by day. Dug well irrigation is a popular adoption option to change the situation in this drought prone area. Irrigation water harvested through solar powered dug well installed through Barind Multipurpose Development Authority can save ripen T-Aman rice, produce low water consuming crops, vegetables etc. and also change the cropping pattern. Rain water is also harvested and conserved in dug well by a funnel type structure above with solar panel. An underground uPVC pipe line system is designed and set up to reduce the water conveyance loss of water which makes the whole irrigation system efficient.

Keywords: Dug Well Irrigation, Solar Power, Rain Water Harvesting and Cropping Pattern.

Introduction

The traditional and still most common method of obtaining water from ground water source in rural areas of developing countries is dug well (*Patkua* in Bengali). In early days dug wells were made manually due to lack of adequate technical resources. But now technical equipment supports the construction of dug well, but excavation is mostly conducted manually as many rural areas and done with cheap labor. Before constructing a dug well, geological sustainability of the area, acceptance within the community and capability of operating and maintaining the system have to be assessed. The type source and soil must have to be allowed for safe excavation for construction of a dug well.

Excessive abstraction of ground water for irrigation through deep tube well (DTW) and shallow tube well (STW), seasonal variability of rainfall, intensity of rain, weather condition, excessive use of ground water for crop production, cropping pattern, inefficient use of irrigation water for rice based cropping pattern are the key factor which govern the water resource degradation in Bangladesh. Due to over draft of water by private DTW and STW, declination of water table is a serious problem in the north west region of Bangladesh. Excessive withdrawal of ground water from this area causing lowering of static water level is creating a negative impact on the environment throughout the country. As a result, natural disaster occurs every year and crop production is hampered. The heavily reliance on ground water and shifting of indigenous cropping pattern and practices may bring a disaster due to continual stress on aquifer (Khan and Sattar, 1994, 1996).

Drought is a common problem in the north western part of Bangladesh. Due to adverse impact of climate change and use of excess groundwater in some areas, water table is going down which leads to withhold the sinking of new deep tube wells. In such situation, dug well is introduced to the water stressed high Barind area. It is an alternate approach of irrigation for the cultivation of profitable, but less water consuming crops. From few years ago, our government has given emphasis on the use of surface water, recovery and storage of surface water bodies and harvesting of rain water and also given priority on the use of solar energy in this context. Bangladesh Government is providing technical information, supports and solution to discourage the use of underground water to prevent salinity intrusion, depletion of ground water, intrusion of dangerous metal etc. Our Government has given emphasis on the use of surface water through dug well (locally called Patkua) by conserving rain water, shifting Boro rice cultivation to Aus rice and winter crops to cash incentives and cultivation of low water consuming crops.

Supplementary irrigations are also being emphasized in crop cultivation. To increase the system productivity it needs to bring diversity in cropping pattern for better utilization of limited resources. Diversified cropping pattern may be an option for the farmers as a coping strategy against risks (Mandal and Bezbaruah, 2013). Dug well is also used to increase groundwater recharge by conserving rain water. Solar pump is also used to withdraw this water from dug well for a short range of irrigation as well as drinking water and other domestic purposes.

These are also the aims of this study. However, the specific objectives are: 1. To avoid over dependency of ground water utilization, 2. To hold rain water and re-use the water for irrigation, drinking and domestic purposes, 3. To create opportunity of small and marginal farmers to provide supplementary irrigation in their rain fed T-Aman rice field in case of scarcity of moisture and 4. To improve climate and environment using solar energy and harvesting rain water and its conservation.

A Few Historical Aspects behind Dug Well and BMDA's Concept

Today, the technology of digging water wells is almost a lost art in the Western world; however, it still is commonly employed in Africa and developing nations. In Greece, many hand-dug wells from the fourth century B.C. were more than thirty meters deep. A well, constructed in Italy in the mid-1500s exceeded fifty meters in depth. In Algeria, hand-dug wells deeper than eighty meters were constructed in the 1860s, and in the American West, large-diameter hand-dug water wells reaching deeper than seventy five meters are recorded in the late 1880s. Materials used to case or line in early hand-dug wells were included wood, stone, brick and mortar.

Both the Old and New Testaments discuss hand-dug wells. The Greek Papyri, 300 B.C. to 600 A.D., also discuss hand-dug wells. These wells, which were as much as twenty meters deep and one meter and forty centimeters in diameter, were lined with stone and cement plaster (Nir and Eldar, 1987). Qanats began as a mother well (Madar Chah) dug vertically from the surface until it intersects the water table. In some cases the mother well may be 100 m deep. From the mother well, a line of vertical wells, ranging from 20 to 150 m apart, were dug down the slope. Their depth decreased from as deep as 100 m near the mountains, to only 1 or 2 m at the valley floor (Clapp, 1930).

By the seventh century B.C., large villas in Greece boasted deep wells lined with stone. Public wells were constructed in the wider streets, and then covered by stone slabs. Recent excavations in Athens uncovered numerous early dug water wells up to 33 m deep (Lang, 1968). Many shallow wells were unlined; however, by the fourth century B.C., terra-cotta-lined wells were common.

One of the more complex water wells of the Middle Ages is located approximately 90 kilometers north of Rome in the City of Oriento. It is approximately 53.15 m deep and 12.21 m in outside diameter and had two spiral staircases constructed in a double helical arrangement. The depth to water was approximately 50.45 m. More than 300 000 bricks were used to construct the well. After ten years of work, this well was completed in 1537 (Ludwig, 1972).

Along the North American east coast, hand-dug water wells were abundant during the later 1700s to the late 1800s. In four years, one well digger, John Robert Shaw, dug more than 177 wells having a combined depth of 795 m. Shaw also dug salt water wells and claimed to be able to locate both fresh and salt water by witching (Shaw, 1807).

Early American water wells were dug both into sand and gravel deposits and into hard rock formations, which required using explosives. Black powder was packed into the holes and, before the development of safety fuses in 1831, was also used as a fuse. Black powder was used exclusively for blasting rock until 1866, when Alfred Nobel mixed nitroglycerin with an absorbent to create dynamite (DuPont, 1942).

The Cahuilla Indians in present-day California were experienced well diggers before the first Europeans arrived in the 1500s. They excavated large-diameter walk-in wells to depths of 10 m near dry streambeds (Bean, 1972).

A well at Selkirk, Kansas, was constructed in 1887 to supply water to the Chicago, Kansas and Western Railway, later renamed the Santa Fe Railroad. The completed well, 7.31 m in diameter and 31 m deep, was lined with quarried stone. The well currently is being considered for listing on the National Register of Historical Places (Walk, 2001).

In Oman, for instance, more than 100 000 hand-dug wells remain in use (MWR, 1998). The technology of hand-dug wells has been lost in most of North America and Europe. However, self-help organizations have kept the technology and practice alive in Africa and other underdeveloped areas of the world (Watt et al., 1977, and Laver, 1987).

Recent scientific literature characterizes hand-dug wells as shallow, low in yield and generally unsatisfactory for extracting potable groundwater. The current concept of a dug well is one that is 6 to 10 meters deep, 2 to 3 meters in diameter and used only by those who cannot afford a drilled well. This characterization, however, is contradicted by the engineering skills evident in many wells dug before the advent of drilling technology.

In BMDA (Barind Multipurpose Development Authority), Dug Well is being constructed using modern and appropriate technology like machine power rig instead of physical man power. Solar energy operated pump is used for lifting of irrigation water and a funnel type structure is also made over the dug well for rain water harvesting. It is a new invention of BMDA.

Scope of the Study

There are many factors which are the causes of water conflicts, groundwater over extraction, irrigation based rice farming, and inadequate water flow in rivers during dry and off seasons, variability in rainfall events and inefficient irrigation. The cumulative effects of these factors have led to water scarcity situations of varying extent for agriculture in Joypurhat ; especially for dry season crops and irrigation based rice farming during Boro season.

The total Agricultural system needs water saving technologies and adoption of an efficient water distribution system that will greatly contribute towards ensuring food security and water resource balancing. Thus, developing innovative practices to save and optimize water use for agriculture will be significant strategic measure and challenge to ensure future food, water and ecological security in this area.

A limited number of research works has been done yet in Bangladesh. Some research has been done on the health and sanitation sector. But in irrigation sector of the north-west region of Bangladesh, there are no such investigations done yet. The following research work will ensure a better prospective in Barind area and will help in the development of agriculture sector in Bangladesh. It may be an example of appropriate technological issue in developing countries.

BMDA's Innovation in Dug Well and its Prospects

Barind Multipurpose Development Authority (BMDA) has been implementing dug-well promotion project since 2015-16 for boosting surface water use for soft irrigation and safe drinking in the high Barind tract. Ultimate goal of the scheme is to reduce excessive use of groundwater and develop an agro-ecological balance for addressing the adverse impact of climate change in this draught prone area. BMDA intends to bring 1,350 hectares of land in 197 villages under vegetable and crop farming through providing soft-irrigation in Joypurhat district.

It will also provide safe-drinking water to 33,750 households and training to 2250 farmers on how to use and promote soft-irrigation.

Moreover, solar pumps are being used to fetch water from those dug wells. As a result, farmers' families have started getting water easily for the purpose of their limited irrigation and house hold uses.

The same solar panels are being used for operating pumps and lighting the pump house areas and as a funnel for harvesting rain water which is also recharging subterranean water level.

Figure: Dug well scheme with cultivation of low water consuming vegetables.

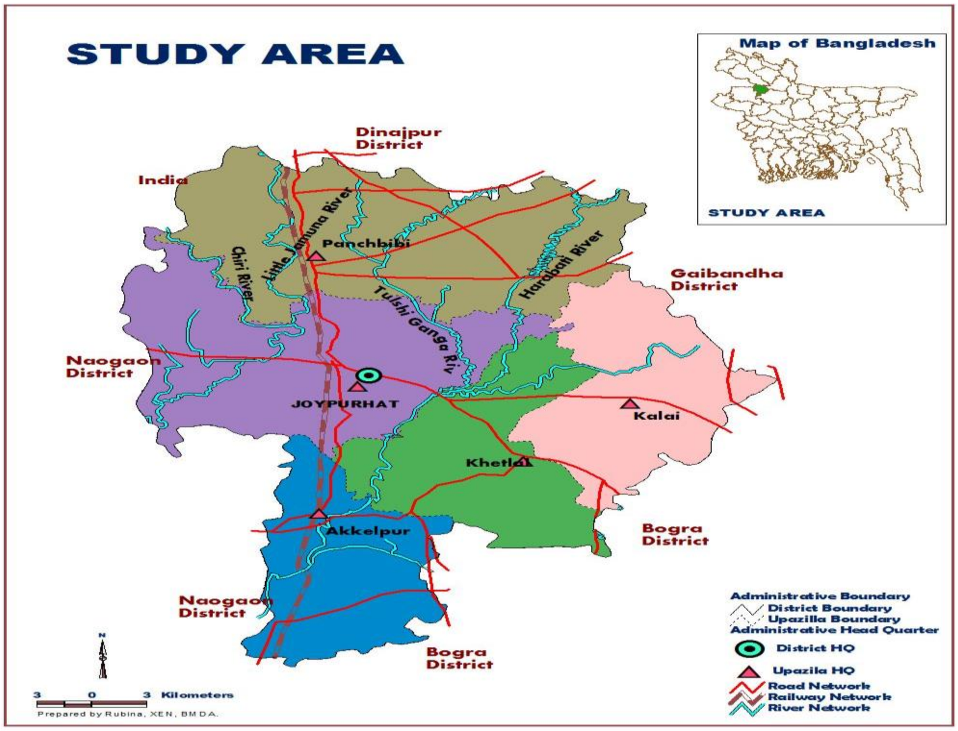
Geographical Coverage

This study is conducted in Joypurhat district, the middle of north-west part of Bangladesh. It is bounded on the north by Dinajpur district, on the east by Gaibandha and Bogra districts, on the south by Bogra and Naogaon districts, on the west by Naogaon and India. Joypurhat district lies between 25^{o} 51' and 25^{o} 17' north latitudes and between 88^{o} 55' and 88^{o} 17' east longitude. The total area of the district is 1012.41 square kilometer (BBS, 2011). Total cultivable land of this area is 75521 hectare (BADC, 2019). The soil is mainly loamy by texture and the land is high to medium (BBS, 2018). Annual average temperature of this district varies from maximum 34.68^{o}C to minimum 11.9^{o}C.

Annual average rainfall is 1610mm (BBS, 2011). Maximum rainfall occurs in between June - August and minimum occurs in between November - February. The weather condition is light dry to dry. The wet season is hot, oppressive and mostly cloudy and the dry season is warm and mostly clear. The average humidity lies between 74% and 77% round the year.

This area is situated in agro-ecological zones AEZ 3 (which is the minor part of the district) and AEZ 25 (which is the major part). AEZ 3 is Testa Meander floodplain and AEZ 25 is Level Barind tract where medium to high land exists. Aman and Boro paddy, potato, sugarcane, banana, jute, turmeric, mustard seed and vegetables are the main crops of this district (BBS, 2011). Apart from the monsoon from mid-June to mid-October the climate is very dry.

An area map of the study area is shown below:



Majority area of this district is very suitable for agricultural crop production especially in cereals and vegetables. The cropping intensity of this area is much higher than the other regions of Barind tract. In 2008, the cropping intensity was 229. But now it is increased to 267 (Nasim et al, 2017), whereas the national average is 194 (BBS, 2018). A crop calendar based cropping area and water needs is given bellow:

Table: 1 Crop calendar based cropping area and water requirements in Joypurhat district.

Cropping Pattern	Year 2009-10		Year 2019-20		Crop Calendar
	Area Covered (%)	Irrigation Water Requirement (IWR) status	Area Covered (%)	Irrigation Water Requirement (IWR) status	
Aman Rice	37	Occasionally	35	Occasionally	Mid July – Mid November
Boro Rice	38	Yes(after every 5-7 days)	33	Yes(after every 5-7 days)	January - May
Aus Rice	1	Occasionally	1	Occasionally	May - August
Others	24	Occasionally	31	Occasionally	Round the year
Total	100		100		

Source: BBS, 2011 and DAE, Joypurhat 2019

Shortage of surface water, serious flooding and river erosion are location-specific critical problems of this area. Low moisture-holding capacity, low organic matter content and low natural fertility are special characters of the Barind tract.

Management Committee of Dug Well Scheme

Each dug well scheme has a separate management committee and the committee is generally formed by nine members of which seven members are from water user group and two members are included from BMDA officials. The farmers use irrigation water from dug well without bearing any cost (money). If any unwanted situation arises among the water users, the committee solves the problem immediately by arranging a meeting. They also create a fund for future expenditure as maintenance cost by collecting a certain amount of money in each month from the farmers. The committee is constituted as follows: 1.Chairman, 2.Co-chairman, 3. Secretary, 4. Cashier, 5.Member (3 persons), 6.Agricultural Adviser and 7.Technical Adviser. The first seven members (1-5) are from water user group and two members (6-7) are included from BMDA officials.

Installation of Dug Well

At the initial stage, BMDA has started solar powered dug well irrigation through installation of 10 dug wells as a piloting program in the year 2017-18 in Joypurhat district (Table 2). But in BMDA, there are 475 numbers of solar powered dug well in Barind area. BMDA has started the program for installation of dug well from the year 2015-16 and till now it is continuing.

Table: 2 A feature of BMDA Dug Well Irrigation Scheme at Joypurhat District.

Location of Dug Well Schemes				Depth of Dug Well (m)	Dia. Of Dug Well (cm)	Cropped Area in 2019-20 (ha)	Benefitted Family (Nos.)
Upazila	Mouza	J.L No.	Dag No.				
Panchbibi	Mohipur	112	2447	36.58	117	4.93	60
Panchbibi	Moh.pur	130	1763	36.58	117	4.53	66
Panchbibi	Bohrompur	132	554	33.23	117	4.94	65
Panchbibi	Shahjadpur	53	4443	37.80	117	5.33	70
Panchbibi	W.Moh. pur	130	1801	32.62	117	4.93	72
Joypurhat	Dogachi	48	1548	36.58	117	5.35	75
Joypurhat	Uttor Joypur	135	1320	36.58	117	4.95	62
Joypurhat	Puranpoil	20	257	33.23	117	4.91	65
Joypurhat	Rampura	125	267	37.80	117	4.93	70
Joypurhat	Borotajpur	114	3505	32.62	117	5.33	64
Total						50.13	669

The diameter of each dug well was 117 cm with a varying depth ranges from 32.62 m to 37.80 m. The diameter of each dug well was 117 cm with a varying depth ranges from 32.62 m to 37.80 m.

Each scheme has an underground irrigation pipe line system.

3 inch and 4 inch diameter uPVC pipes were used for each scheme with a length of 360 meter to 425 meter.

The total numbers of 14 faucets were constructed as outlet through which irrigation water distributed in the crop land properly.

uPVC pipes were used to minimize water losses.

Fig. A faucet with underground uPVC irrigation pipe line in dug well scheme.

Total irrigated area under dug well in Joypurhat was 50.13 ha in the year 2019-20. The crops grown were mostly low water consuming. In BMDA, there are such 475 numbers of BMDA's dug wells in high Barind area since beginning in the year 2015-16 which are already operating. Farmers are more interested in BMDA's dug well irrigation.

Impacts on Cropping Pattern

The cropping pattern of Joypurhat district is normally rice based. But this technology has turned the situation already. People are growing wheat, potato, maize mustard, vegetables and many others low water consuming crops. Many farmers opined, due to the lack of rainfall, the yield of vegetables in dug well scheme are better than early days before 10 years back. More over the quality of vegetables are very good and its market price is high.

At present, the cropping pattern has changed abruptly which has given a positive impact to the people. More cropping lands which have been transformed into triple and quadruple cropping lands have enhanced cropping intensity by 267%.

This difference is not only due to dug well irrigation. There are many factors involved in the whole system such as farmers training, inputs supplied to the farmers, advertisement among the people about change in perception at the farmers level. A change of cropping pattern is given bellow.

The table shows that the main crops like Boro and Aman puddy have decreased, on the other side, Maize, Wheat, Mustard, Lentil, Vegetables and others crops have increased after 10 years.

Table: 3 Cropping Pattern before and after implementation of dug well.

Crops	Cropped Area in 2009-10 (%)	Cropped Area in 2019-20 (%)	Remarks
Aus(Paddy)	0.234	0.234	unchanged
Aman(Paddy)	36.906	34.897	**decreased**
Boro(Paddy)	38.593	33.116	**decreased**
Maize	0.229	0.401	increased
Wheat	0.976	1.162	increased
Potato	19.167	18.281	**decreased**
Mustard	0.715	5.347	increased
Lentil	0.073	0.103	increased
Vegetables	1.854	2.790	increased
Others	1.459	3.668	Increased
Total	100	100	

Calculation of Rainfall collected per Unit Installation from Solar structured Funnel

After knowing the precipitation and the area of collection surface, it is possible to calculate the annual amount of water that can be collected through the solar structured funnel of 13 meter in diameter.

The funnel is made by MS plain sheet. G.I (galvanized iron) pipes and MS angle bar are used as support to the structure. Local technicians can make it in the scheme site by their own arrangement. Solar panels are placed above the funnel.

Fig. Funnel above a dug well used as a rainwater receiptor.

A table of collection of annual rainfall per dug well is given bellow:

Month	Monthly Average Rainfall (mm)	Runoff Coefficient (c)	Funnel Area(m^2)	Volume of Water stored (m^3)	Remarks
January	1.70	0.85	133	0.19	dry period
February	13.19	0.85	133	1.49	dry period
March	12.64	0.85	133	1.43	dry period
April	62.30	0.85	133	5.98	
May	141.62	0.85	133	16.01	
June	209.17	0.85	133	23.65	
July	217.39	0.85	133	24.57	
August	196.38	0.85	133	22.20	
September	213.19	0.85	133	24.10	
October	65.78	0.85	133	7.43	dry period
November	3.79	0.85	133	0.43	dry period
December	0	0.85	133	0.00	dry period
Total	1137.15			127.48	

Source: Monthly average rainfall data taken from BMDA, 2019 (last 10 years average).

The above table shows that annually 127.48 m^3 rainwater is harvested from a dug well considering a runoff co-efficient as 0.85 for the roof top surface of the funnel.

This amount of rain water is using alternatively for irrigation and drinking purposes; mainly aboriginal people are using this water as drinking purpose.

People's Reaction and Opinions on Irrigation Water Utilization

BMDA's environment friendly dug-wells irrigation has spread the entire study area and saved the farmers as well as environment. This technology has removed an acute water crisis exists in the study area resulting in the untold sufferings of the poor and other marginalized communities. Farmers in this area were facing severe water crisis for decades, but due to installation of dug well in the area, farmers and their families are benefited. They are getting their daily drinking water and also cultivating crops and vegetables with the same water. Agro-ecological balance is being restored by massive cultivation of different crops and vegetables.

This situation is gradually mounting pressure on groundwater in this drought prone area. So, extension of dug-well technology and its proper uses can be the vital means of mitigating the crises of irrigation water. Since lifting of underground water through deep tube wells is becoming tougher day by day and options for surface water are also very limited, there is no alternative than dug well. Thousands of hand-driven tube wells are remaining out of use every dry season due to the fall of the water level in the area, Millions of people in the dried up areas are now dependent on dug wells both for drinking and irrigation water.

Concluding Remarks

Due to adverse effect of climate change and use of over draft of ground water through DTW and STW for irrigation, in some areas water table is going down day by day. Sinking of new DTW has been stopped. In such situation dug well is introduced to water stressed Barind area. It is an alternative approach of irrigation for low consuming crops to change the cropping pattern which is an environment friendly approach in BMDA. With the introduction of solar energy associated with dug well, rain water is harvesting to contribute the increase of ground water recharge. The solar pump is used to withdraw this water from dug well for irrigation as well as drinking and domestic purposes. The poor and aboriginal people are also using dug well water as drinking purpose. Dug well has now given a new hope to the farmers and the people in this water stressed area.

This technology is totally environment friendly and of low cost. Farmers can protect his/her crop from the impact of draught and increase crop yield resulting in more income earning. It can also resist down ward movement of ground water layer, which will contribute to improve the environment and enhance sustainable development. In rain fed areas where irrigation water is very limited and crop lands remain fallow in Aus rice season, can be taken under production.

This technology can be implemented in both high Barind and low Barind areas of north western part of Bangladesh. In farmlands with no irrigation source, popularity of rain water harvesting through the construction of dug well for supplementary irrigation for T-Aman rice during drought period and also for irrigation in low water consuming crops.

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