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Agricultural Scenario and Solar Irrigation System of Bangladesh

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ABSTRACT
Bangladesh is an agronomic country where two third of the total population directly or indirectly involves with agriculture and about 14.75% of gross domestic product (GDP) emanates from the agriculture sector.Although Bangladesh's economy is dependent on agriculture, she is not self-sufficient in food.Besides, frequent natural disasters such as flood, drought, and cyclone cause damage to crops every year. To provide food for her overpopulation, a large amount of food grains is imported every year. The total amount of cultivable land is about 85,60,964 hectares, of which 1154141 hectares land are being unirrigated every year.The typical irrigation systems of Bangladesh are primarily diesel based and electricity based pump. At present, 1.31 million diesel based pumps and 313,929 electricity based pumps are in operation for irrigation and it demolishes above 1.06 million tons of diesel and about 1400 MW electrical power individually. The power crisis in Bangladesh along with high diesel cost make the solar irrigation system as a promising alternative to power and diesel based pumping systems. The main objective of the study is to present a review of agricultural scenario, conventional pumping method, the prospect of solar pumping in Bangladesh. The study focuses on the update on advancement, barrier and remedies and socioeconomic benefit of the solar irrigation system. Since, Bangladesh is an energy starving country and most of the farmers are poor, therefore solar irrigation may be supportive for the farmer as well as in the total crop production in Bangladesh.

Keywords: Bangladesh, Agricultural scenario, pumping method, Solar irrigation, Advancement.

1. Introduction

Bangladesh is a middle income South Asian country and its economy ranks 46th in terms of nominal gross domestic product (GDP). It covers a total land area of 147,570 square kilometers [1]. Bangladesh has a population about 162.9 million [2], making it one of the densely populated countries of the world. Bangladesh is an agrarian country, where the majority of the land is being utilized for agriculture [3,4]. From the World Bank report, the farming area is just over 70% of the aggregate land. The country has about 14.76 million hectares of aggregate land, of which 56% are net irrigable [5]. The total land utilization pattern of Bangladesh. The forest area covers only 11.73% of the total land. The net cropped area is 69.4 % where more than 16% lands are not used for cultivation [6].Around 60-70% of the population involves agriculture for their livelihood. But recently, the portions of agriculture in GDP declined steadily in recent years, which were recorded at 15.51%, 14.77%, 14.17%, and 13.75% in the years 2014-15, 2015-16, 2016-17 and 2017-18 respectively [7]. Agriculture, forest and settlement used the majority of the land area in Bangladesh. A fraction of the land area is being used to meet industrial and other miscellaneous social and administrative needs. Moreover, the existing cultivable land areas are being acquired by new industries and residences to meet the vital demand of the growing population.

Bangladesh is mystically enchanted with auspicious natural resources for the production of crops all year round. She produces rice, wheat, sugarcane, pulses, tea, jute, maize, potato, oilseeds, vegetables, various spices. Among them, rice is the overwhelming harvest in Bangladesh, covering 75% of cropped areas, and includes 70% of the estimation of product yield [8]. According to the fiscal estimate of BBS, the volume of food grain production in FY 2015-16 stood at 386.93 lakh tons among which Aus accounted for 22.89 lakh tons, Aman 134.83 lakh tons, Boro 189.37 lakh tons, wheat 13.48 lakh tons and maize 26.36 lakh tons. In spite of producing large quantity of food grains per year, Bangladesh is not self sufficient in food and as a result, she needs to import lots of rice per year which accounts for a loss of foreign currency. The main barriers for agricultural growth includes weather and climatic variations such as too little or too much rain, cyclones and storm surges, floods and increasing salinity along the coastal areas, drought, heat waves, cold and fog and water logging,etc. Due to frequent drought and scarcity of water during dry season, a significant amount of lands remains uncultivable every year. Earlier, irrigation was done by river water. But, recently many rivers suffer from the scarcity of water, especially in dry seasons.Therefore, underground water has been becoming the main source of water for irrigation which enforces the farmers to use diesel and grid-connected water pumps.

The energy demand of the country is growing significantly due to the quick increment of population, rapid alteration in economy and industrializations. Incrementing energy demand is not only diminishing the reserve of fossil fuel e.g natural gas & coal but additionally affecting the environment. Fig.1 illustrates the power consumption pattern of the country. Inadequate amount of power generation retards the economic development as well as desertification

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problems in rural area. The energy is utilized in all sectors of the economy including domestic, agriculture, industry, and other service sectors. Domestic sectors consume about 23050 MkWh electricity which is about 50.89% of total power consumption occurs [9]. The electricity demands in agriculture sectors have been steadily increased and it consumes about 3.61% of country's energy. Besides, new pumps have been installed in every year to meet the demand of irrigation during dry season. Fig.2 shows the installation of new pumps for the last few years. The numbers are increasing and the corresponding energy require driving them increases which results in high power consumption in agricultural sectors. Actual demand of electricity was unable to meet in the last few years due to insufficiency of generation. Therefore, load shedding has increased and Bangladesh is currently facing a shortage of 250MW electricity. The situation becomes terrible during irrigation seasons, when gap between actual energy demand and supply reaches around 2000 MW along with the poor quality of power services such as frequent voltage fluctuations, unreliable and erratic supply especially in rural areas. Due to lack of proper electricity, farmers depend on diesel based pump. Bangladesh government usually provides subsidy BDT 22-26 per liter of diesel to make diesel pumping affordable to the farmers which creates an extra pressure on domestic economy. Over 1.75 million irrigation pumps are being utilized in the country of which 82% are diesel engine operated and 18% are electrically operated [10].

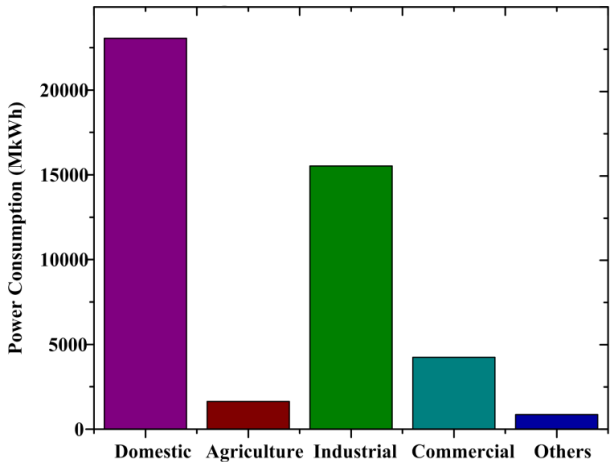

Fig.1 Power consumption pattern of Bangladesh [9]

Approximately 40% individuals of the country live in the remote zone, which is far from subsisting grid line and sometimes isolated from the main land. In some cases, the grid power won't be accessing the majority of the remote and disconnected region for the following 20-50 years. Besides, the underground water level in some regions of the country, e.g Varendra area is too deep and not practical to withdraw water by diesel pumps. In this manner, many land areas still remain non-irrigable and un-cultivable during dry seasons. Many areas of Bangladesh (Charland, hilly area, coastal area, etc.,) are out of grid connection and hence they are not cultivated properly. Less arable land and limited natural resources increase the importance of developing new agricultural technologies. Therefore, it is high time to incorporate sustainable methods to irrigate cultivable land to increase food security as well as economic development. Solar irrigation system would be a probable solution.

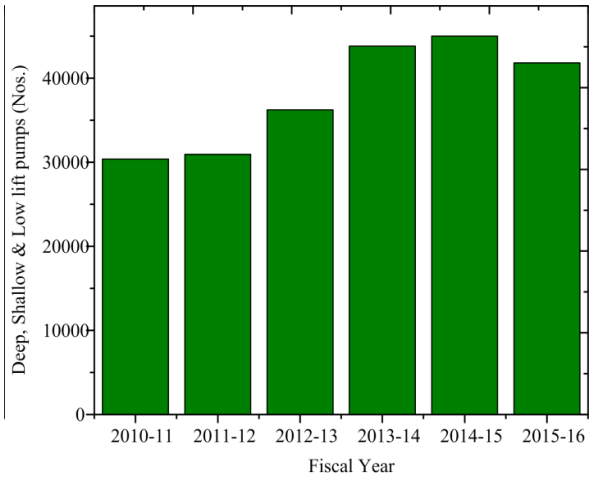

Fig.2 Pump installation scenario in recent years [6]

Solar energy is more reliable and richly available in Bangladesh with a variation of average irradiation in between 4 and 6.5 kWh/m^2/day [11]. Introducing solar irrigation will not only reduce burden on energy sector but also encourage farmers to cultivate more land under irrigation which helps to improve rural economy as well as national economy. Solar photovoltaic pumping offers alternative way to the farmers of Bangladesh from the energy crisis [12-14]. Abu-Aligah [15] demonstrated that the photo voltaic pumping system is a good alternative for irrigating crops in the off grid areas. It was reported that solar based pump was much cheaper on life-cycle cost basis than diesel engine for small to medium sized wells [16]. Proper policy and financial subsidies should be provided by the GoB to popularize solar pumping within the country [17-18]. This paper represents the agricultural scenario, conventional pumping method, prospect of solar pumping, solar irrigation system and focuses on update on advancement, barrier and remedies and socioeconomic benefit of the solar irrigation system in Bangladesh.

2. Agricultural Scenario of Bangladesh

Agriculture is the huge employment sectors in Bangladesh since it utilizes 47% of the total work force and involves 16% of the nation's GDP [19]. The majority of the populations earn their living from agriculture. There are three types of aggregate land in Bangladesh including one crop land, two crop land, and three crop land. In the year of 2016-17, the one crop land is 2354821.74 ha, two crop land is 3847274.49 ha and three crop land is 1715430.38 ha [10]. Rice is the staple food of Bangladesh, which contributes about 70%

of total calorie supply and about the half of the aggregate protein. Bangladesh is the fourth most rice producer in the world in which about 75% of agricultural land is planted to rice [20]. Bangladesh is also a large exporter of jute. There are other agricultural crops, i.e., wheat, potato, pulses, vegetables, spices, tea, which are partly produced and the rest are imported to meet the domestic demand. The most cultivable region of Bangladesh is includes Borguna, Barisal, Chittagong, Comilla, Noakhali, Mymensingh, Narsingdi, Bagerhat, Jessore, Naogaon, Rajshahi, Rangpur, Sylhet region. In the above area, all types of crops are grown up in huge quantity. Table 1 demonstrates the production of major agricultural crop from 2008-09 to 2015-16 [21]. In 2016, the production of rice was 34.7 million tons and the production of jute was around 7.55 million bales.The production of food is increasing per year due to incorporation of new techniques but it is inadequate to feed the over population. Moreover, various natural calamities such as floods and drought damage our crop and causes food shortage. As a result, in spite of producing high amount of food grains, Bangladesh is not self-sufficient in food. Every year it often requires toimports huge amount rice from the neighbor countries to satisfy its rice demand and to confront nourishment emergencies because of the dry season, surge and numerous other catastrophic events. Bangladesh turns out to be a net rice importing country due to the huge domestic consumption. To keep pace with the population increase, demand for import also needs to increase to mitigate food crisis. The increasing volatility of international grain markets over the past few decades results a consumption of huge foreign currency. Fig.4 shows the rice and wheat import scenario for the last few years and their corresponding cost. Imports of rice grains are low compared to wheat mainly due to the adequate domestic supply of rice. In 2016, Bangladesh imports about 0.07 million tons of rice and 5.5 million tons of wheat which cost about 119 and 915 million USD respectively. The country`s rice consumption needs are estimated at around 34.8 million tons in FY 2014-15 slightly up from an estimated 34.6 million tons in FY 2013-14 [22]. Bangladesh imports rice from India, Srilanka, Vietnam, Combodia and Myanmmar. In 2015-16, wheat imports are forecast at 3.8 million tons where the actual amount was 4.72 millions ton. The consumption of wheat follow the increasing trends in recent year which is expected to cross 6.72 million tons in 2017. Bangladesh sources wheat from India, Russia, Ukraine, Canada, Australia, and the United States.

Table 1 Production rate of major agricultural crops in Bangladesh [16]

Year	Rice	Jute	Sugarcane	Tea	Pulses	Oilseeds	Tobacco
	Production '000' tons	Production '000' Bales	Production '000' tons	Production '000' lbs.	Production '000' tons	Production '000' tons	Production '000' tons
2008-09	31317	-	5233	130073	196	661	40
2009-10	31975	924	4491	132277	218	786	54
2010-11	33542	1523	4671	133380	232	730	79
2011-12	33889	1452	4603	133379	240	787	85
2012-13	33833	7611	4469	139994	265	804	181
2013-14	34357	7436	4508	145728	352	844	85
2014-15	34710	7501	4434	145727	378	934	94
2015-16	34710	7554	4208	142198	378	934	88

3. Conventional Pumping Method

In Bangladesh, surface water, ground and rainwater are the main sources of irrigation. About 795,000 million m^3 surface water discharges through the two main rivers i.e Ganges and Brahmaputra **[**23**].** In the dry season, Bangladesh extremely experiences shortest of water particularly for irrigation and consequently the farmers to a great extent rely upon groundwater at the dry season.The DTW, STW, and low lifting pump LLP are ordinarily utilized for substantial and medium scale water lifting in Bangladesh. Table 2 shows the various type of tube wells utilized for irrigation in Bangladesh. In the year of 2015-16, a total of 1,627,166 irrigation pumps were operated to irrigate 5,313,729 ha lands. Among them 313,909 were operated by electrical motor to irrigate 2,248,697 ha. and 1,313,257 were operated by diesel engines to irrigate 3,065,032 ha land [**24**]. Besides in the fiscal year 2015-16 29,718 ha lands were irrigated by Manual & Artesian well method, 18,336 ha lands were irrigated by traditional method and 1,28,564 ha lands was irrigated by gravity flow.About 17.55 millions farmers get the benefits irrigation and this number is increasing steadily. About 42.3% areas are irrigated by electricity and the rest by diesel based pumps. Diesel pump consumes about 18.1% of country's total annual petroleum consumption. The government owned organization BADC and BMDA operates only 2.11% of total pump, where rest 1592908 pumps are operated by other organizations and private entrepreneurs. Fig.3 show the area irrigated under different crops. In 2014-15, about 18.17 million acres land are irrigated by different pumping methods in Bangladesh. Rice including aman and boro covers about 13.54 million acres of crop land.Farmers in areas without electricity grid coverage are compelled to use diesel-powered irrigation pump. Every year, diesel pumps consume 1 million tons of diesel worth $900 million [25].

Table 2 No of different types of tube wells used for irrigation in Bangladesh [24]

Fiscal year	DTW		STW		LLP		Total
	Operated by electricity	Operated by diesel	Operated by electricity	Operated by diesel	Operated by electricity	Operated by diesel	
2012-13	32,412	2910	253,473	1,270,136	10,856	159,713	1,729,500
2013-14	33,179	2855	273,755	1,290,036	10,417	160,624	1,770,866
2014-15	33,714	2852	276,347	1,273,364	10,496	156,679	1,753,452
2015-16	34,647	2332	269,847	1,147,161	9415	163,764	1,627,166

The consumption of diesel fuel to irrigate these land emit excessive CO_2 emission which is a threat to the environment. The high price of diesel puts extra pressure to the farmers and result in excessive production cost which is a main barrier for sustainable agriculture.

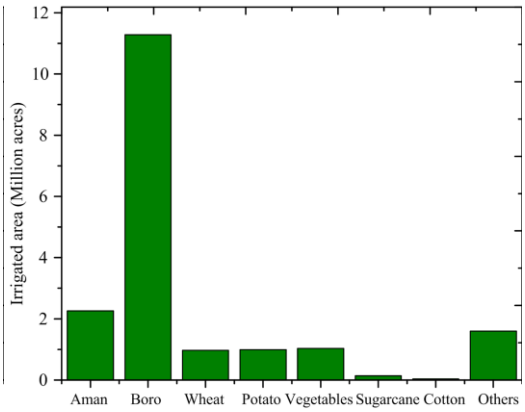

Fig.3 Irrigated area for different crops in Bangladesh [6]

4. Solar irrigation system

Solar powered irrigation pumps are a low cost and reliable irrigation alternative as Bangladesh is not enriched in power generation.

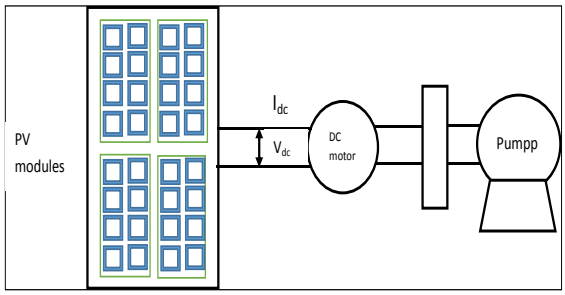

Fig.4 Typical block diagram of a direct coupled DC solar irrigation system

A solar pump can supply water for virtually three crops irrigations along the year. A solar irrigation system consists of a PV array, a DC motor or an AC motor pump set and a powerful converter with a controller. Fig.4 shows a typical block diagram of a direct coupled DC solar irrigation system.

In Bangladesh, the solar irrigation system has paramount advancement in the last 10 years. At the beginning, centrifugal pumps were mainly utilized in solar irrigation system having the hydraulic efficiency of 25-30%. Later higher capacity multistage submersible pumps were introduced, which can withdraw waterfrom a few meters to few hundred meters with distribution capacity up to 500 m^3/h. Multistage solar irrigation system consists of a PV array, a DC-DC converter, a DC-AC inverter and a motor pump set. In a solar irrigation system, the pump utilizes the produced electricity in solar panel. The management of AC or DC current is controlled by the electric motor where the speed and output power are adjusted by the controller. The system is feasible to be used as the alternative of conventional diesel based pumping system. The main cost of the solar pump is the Panel cost (45%) followed by the installation cost (18%), motor cost (16%), pump cost (10%), and pipes and fittings cost (4%) [20].

5. Solar Energy Resources in Bangladesh

Bangladesh is a semitropical region lying in northeastern part of South Asia gets plentiful sunlight year round due to its geographical locations **[**26**].** Bangladesh receives 70% of sunlight During dry season. It receives an average solar radiation of 4 to 6.5 kWh/m^2/day and the yearly solar radiation is as high as 1700 kWh/m^2**[**27**].**

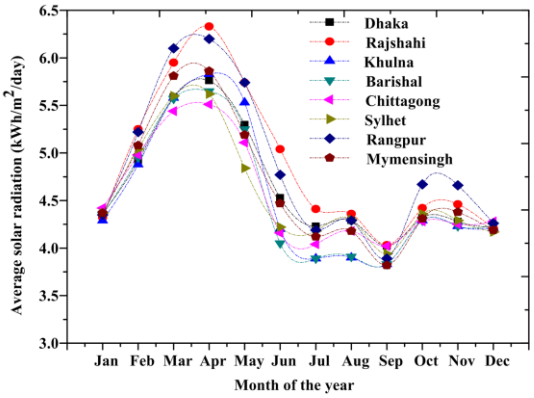

Fig.5 Incident solar radiation on different locations in Bangladesh throughout the year [27]

Fig.5 shows thesolar irradiation on the eight divisions of Bangldesh round the year. Greatest measures of

radiation accessible in the month between March-May and least during November to January**.**Bangladesh has the normal bright sunshine hour in the dry season of around 7.6 hours and in monsoon season of around 4.7 hours per day. The maximum sunshine hours got is in Rangpur with readings going from 3.6 to 8.9 hours and in Chittagong 3.7 to 8.7 hours. Ideal locations for a solar power plant should have flat lands with minimum cloud cover, high solar radiation availability and exhibit high average sunlight hours throughout a year.The lowest cloud average is in Rajshahi and Khulna with readings ranging from 0.6 to 6 okta and 0.4 to 6.4 okta respectively. Rajshahi receives the most solar radiation with the ranging from 4.03 to 6.33 kW/hour/m^2.

7. Advancement of solar irrigation in Bangladesh

Because of the fast growth of population in Bangladesh, a remarkable percent of residents will live without power. Besides, the future capacity shortage threatens the grid expansion rate to connect rural areas, which directly affects the irrigation system in rural areas. In order to solve this problem, Bangladesh government has prepared a renewable energy policy in 2008 effective from 2009, where an objective was set to create 2000 MW electrical power by 2020 from renewable energy source assets.

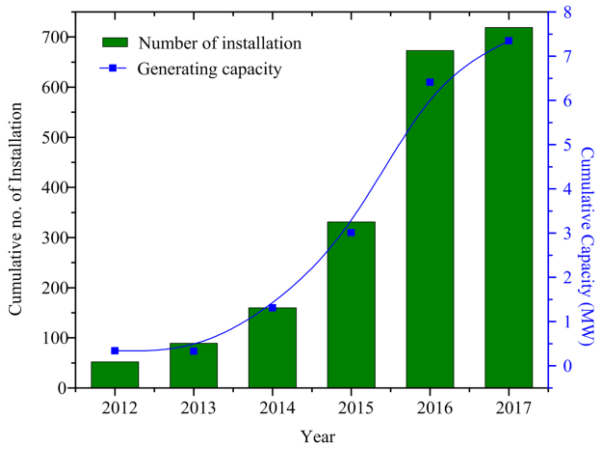

Fig.6 Cumulative increasing number of solar irrigation for last 6 years.

At present, about 719 solar irrigation pump with a capacity of 7.5 MW are being operated with the support of IDCOL in the different locations of Bangladesh [28]. IDCOL financing solar irrigation projects by receiving fund from World Bank, Asian Development Bank, Kreditanstalt fur Wiederaufbau (KfW), Japan international Corporation Agency (JICA), Global Partnership on Output-Based Aid (GPOBA) and Bangladesh Climate Change Resilience Fund (BCCRF).IDCOL has an mission to install 1550 solar irrigation pumps by 2018. IDCOL gives up to 50% subsidy and arranging 35% soft loan with the assistance of donor agencies. Under this programme, owners or individual investors of the irrigation system required to contribute just around 15% of project cost. The soft loan may have a maximum tenure of 8 years with 9 months grace period and an interest rate of 6% per annum.

7. Socioeconomic benefit

Environment friendly and cost effective solar irrigation system getting popular among the farmers of Bangladesh since it creates a scope for sustainable agriculture practices over diesel based irrigation system. Besides, the farmers will be able to enhance their product yield through irrigation round the year by solar irrigation which not only brings various socioeconomic benefit to the society but also reduces the dependency on conventional energy system. It also reduces government's subsidy for agriculture as well as import of diesel fuel. In remote areas, solar irrigation system witnesses rapid adoption since the irrigation cost has dropped almost half compared to diesel based irrigation system. They are more reliable, operated without pollution and noise, easier to install and lower maintenance cost compared to conventional pumping methods. It also motivates the farmers to shift their attention from expensive, CO_2 emitting diesel powered water pump as it provides reliable water supply throughout the year with benefits to good harvest and household income. Solar pumps require fewer amount of land and water in operation with minimum wastage since additional drainage system is not required to irrigate the land. It will also deceased the burden of government's ability to produce electricity and the cost of energy production. Solar irrigation has a high potential value as it brought sustainable benefits to agronomy.

8. Barrier and Remedies

Though solar energy is abundant in nature and environment friendly, installation of solar pump requires extensive infrastructure and equipment. Since most of the farmers in Bangladesh are poor they can't afford to install a solar irrigation system due to high initial investment. This is the main barriers for rapid expansion of solar pumps. Besides, the raw materials required for the photovoltaic cells, reflectors and other auxiliaries are imported, these increases the cost of solar system. Due to the imposition of import duty on solar panels and other accessories, the initiatives taken by different organizations to promote solar irrigation in agricultural sector faces serious hindrance. As a result, this system failed to become economically feasible and the investors show less interest even after government provides 50% of the initial cost. Maintenance and repairing is an important concern since there is a lack of skilled technicians and experts. Artificial solar based irrigation system is mainly used for boro paddy cultivation in dry season. The solar panels are able and continue to generate electricity throughout the year. But this energy is used only in dry season and remains unused during the rest of the year since there are no such facilities to supply this unused electricity to the grid or other consumers. This situation makes solar irrigation system less effective both technically and

financially. In order to irrigate crop land, solar irrigation extensively uses ground water. Since, ground water has limited reserve, excessive use causes underground the aquifer to fill up by saline water from the sea. This adverse effect is alarming signal for the agriculture in many areas of Bangladesh. Besides, solar irrigation creates unemployment to the community whose income depends on diesel based pumping system and hampers their livelihood security. Social awareness's are required to promote solar irrigation in Bangladesh through publicity in print and social media. The government can provide more subsidy and exempted tax from solar accessories to make it feasible for the farmers.

9. Conclusion

This paper reviews the socioeconomic status of Bangladesh in terms of its current scenarios of agriculture, rice production, methods of irrigation, energy and environmental conditions, solar irrigation and its advancement to prospect. All that discussion delivers a clear forecasting that, solar irrigation could be one of the vital options to create sustainable development in agriculture. Because the main advantages of solar irrigation pumps over hand pumps or diesel based pumps are their practically zero maintenance, long useful life, zero requirements of fuel, zero contamination, and easy to install. The review helps to draw the attention to the investor to invest in this field and helps in further research. Keeping in view the high installation costs of solar water pumps especially for large irrigation and water supplies, more incentives are required to be provided by governments to make the technology further attractive alternative to diesel and electrical water pumping.

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