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Research Article

Understanding the Economics of Solar Powered Irrigation System in Bangladesh

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ABSTRACT

Solar pump is a more environmental-friendly irrigation option for farmers in Bangladesh. Researchers have found that using solar pump for irrigation is more cost effective. Researchers have found that using solar pump for irrigation is more cost effective as well as less damaging for the environment. Moreover, this relies on renewable energy sources that make it more efficient. Against this backdrop, the objectives of the present study were to understand the profitability analysis of using solar pumps instead of the diesel-run pumps for irrigation and also to identify its determinants. The study collected primary data from four upazilas of Jhenaidah district, purposively selected as the study site. Data were collected from the respondents whose families are involved in agricultural activities. For the analysis of collected data, the study used cost-benefit analysis, while a logit regression analysis was also done for understanding the determinants of using solar energy for irrigation. It is found that the benefit-cost ratio for using solar pump for irrigation by the farmers is 0.277, which implies that the cost is more than the benefit if the households adopt solar pump instead of diesel pumps. On the other hand, the Logit regression analysis found that bigger household size, nearby water sources for irrigation, perceptions on improved production and higher current year yield significantly influence the usage of solar pumps for irrigation. On the contrary, if households were entitled to share irrigation facilities, they are less likely to use solar pumps for irrigation.

***Keywords**: Demographic and socioeconomic analysis, profitability analysis, logit regression analysis*

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Introduction

Solar photovoltaic water pumping (SWP) is a system which uses energy from solar photovoltaic (PV) panels to power an electric water pump basically, the entire process, from sunlight to stored energy, is decent and simple. Solar pumps and South Asia's energy-groundwater nexus: exploring implications and reimagining its future (Shah et al., 2018). It has been a promising field of research for more than 50 years. In the early 1970s studies were susceptible to explore the potential of SWP as feasible, viable and economical (Sontakeet al., 2016).

It consists of mainly photovoltaic panels, inverters and AC pumps. At first, photovoltaic panels generate DC current using solar radiation after that this DC current is converted to AC current through the inverter. Finally a submersible AC pump is running by using this AC current. It is important to consider that there is no use of any battery here for minimizing the maintenance cost so there is no chance for preservation of extra power (Kelley et al., 2020).

Bangladesh is supporting her 164 million people with some 147,570 km^2 areas of land (Statista 2020). It would rarely be possible without the expansion of agriculture activities. Although with time the relative importance of agriculture for its economic growth has been decreasing, even now two-third of the total population are directly & indirectly depends on agriculture. After the independence, the country has achieved remarkable successes, particularly in food production. Irrigation and use of high yielding varieties (HYV) seeds have contributed a lot in this respect. Irrigation in Bangladesh traditionally was powered by diesel or liquid fuels; but with time and expansion of grid line electricity, irrigation service now is mostly run by electricity (Islam et al., 2017).

SREDA (2017) found that about 3.20 lakh pumps are run by electricity to irrigate crops on a total of 54.48 lakh hectares in the dry season and some 1,700-1,800 megawatts of electricity are consumed for irrigating rice fields. Presently, Bangladesh has 1.34 million diesel pumps and these consume at least 1 million tons of diesel worth $900 million and also emit 7 million tons of carbon dioxide per year which worsen the environment badly. Total 2,884,614 metric tons of diesel was imported in 2011-2012. However, Bangladesh is a semi-tropical region which gets plentiful sunlight by year round. For example, highest solar radiation is 1700 kWh/m2 and daily average solar radiation of 4–6.5 kWh/m2.

Solar energy in recent years has been emerging as a viable and clean alternative to hazardous liquid fuels. Studies indicate that solar powered irrigation system can potentially reduce GHG emissions by more than 95 percent compared to alternatives fossil-fuel driven irrigations. At present, about 1270 solar irrigation pumps installed by IDCOL, 50,000 solar irrigation pumps to be set up by IDCOL by 2025 and 2000 solar irrigation pumps to be set up by BERD (IDCOL, 2018).

Marzia (2018) found that solar irrigation in Bangladesh by the year (2011-2017) is on an increasing trend. Chandel et al. (2015) found that India was initiated a project through the Ministry of New and Renewable Energy (MNRE) in 1992, which is the first project of India. Even the country installed 13,964 and 17500 solar pumps during 1992-2014 and 2014-2015 and targets 1 million install by 2021. It is also understood that the PV module cost has been spilling significantly in the country and was available at a rate of US$ 0.59/WP in 2014 with compared to around US$ 1/WP in 2012. It is said that, PV module enacts 60-80% of the PV pump systems.

Hossain et al. (2015) found that, the main cost of the solar pump using in irrigation purpose is mostly consists of the panel cost (45%) followed by the installation cost (18%), motor cost (16%), pump cost (10%), and pipes and fittings cost (4%). Estimated results of the study, capital cost of diesel & PV-operated pumps are respectively US$ 512 and US$ 769, respectively. However, running cost of solar pump is very low but it is higher for diesel pump due to diesel and oil costs including repair and maintenance cost as well total emission of carbon. Kanna et al. (2020) found that initial cost, servicing cost and maintenance cost and cumulative total respectively, USD 46644, USD 1274, USD 69847 & USD 117738.

However, not many studies are found to address the issue of economics of solar energy for irrigation and also identify the major determinants of farmers' decision to adopt solar powered pumps in Bangladesh, although some studies were conducted to assess economic benefits of using solar power for irrigation in Bangladesh, but no recent study is found in this context.

Goal of the Study

The overall goal of the present study was to make an assessment of the economics of solar energy-run irrigation pumps and also to identify the determinants of using solar energy in case of irrigation in in the study area.

Specific Objectives of the Study

The study was designed to undertake the following specific objectives:

- ✓ To understand the economics of using solar energy for irrigation; and
- ✓ To identify the determinants of using solar energy for irrigation in the study area.

Irrigation and Solar Pumps

Irrigation is one of the most important factors for agricultural production as it helps crops to gain more energy and nutrition to grow more properly whereas the regions which are deprived from irrigation in the Sub-Saharan Africa and South Asia suffered a lot in crop production due to lack of irrigation (FAO & GIZ, 2015).

Farmers depends on various sources for irrigation, one of the most ancient factors of irrigation is rainfall, then after the introduction of deep tube-wells the dependence for irrigation shifts to it, then farmers used motorized tube-wells, diesel for irrigation (Shah et al, 2004; Agarwal & Jain, 2015). One of the most important additions for irrigation is solar powered pumps which are seemed to be a game changer in crop production as they are found out that solar powered pumps enhance diversity in crop production & food security (Alofe et al, 2016; Burney et al, 2014).

The use of solar module pumps has seemed to be increased as government is increasing subsidy for using these pumps as they are environment-friendly and also the price is being cheaper than other related instruments for irrigation (Bloomberg, 2016). The market of solar pumps is now expanding and expected to reach 1.5 million units per year, 2022 (Grant View Research, 2016).

As solar pump helps to produce more income for farmers as crop production pattern changes, cost reduces and wastage of water also decreased (Suman, 2018). Solar pumps are also proved to be more profitable and less risky by a feasibility study conducted by Karim & Shankar (2017).

Demand of the Solar Pumps

There are several factors that influence the upward slopping demand for solar pumps for irrigation, which is being discussed and explored by several researchers. A research conducted on the rural farmers of Punjab found that one of the important determinants of solar pump using is the awareness level of farmers influencing most to adopt solar pumps for irrigating their crop fields along with performance expectancy, social influence, price value, behavioral intention, perceived behavioral control, subjective norms intention (Venkatesh et al., 2012; Kumar & Syan, 2020).

Perceived benefit of using solar pumps is measured by performance, benefits and quality derived from its usage (Jamie et al., 2017). Moreover, reliability, responsiveness, assurance, empathy and tangibility also work as catalyst for the usage of solar products (Kumar et al., 2019).

Solar energy products seemed more cost-effective, reliable and environment-friendly as economic sustainability measured by input costs for solar irrigation, revenues from cultivation due to the use of solar pump and higher cost of alternative irrigation such as diesel or electric pump speaks in favor of solar pump being more economic than others which is found out in several research (Tehreem et al., 2018; Jing et al., 2018; Stougie & Van der kooi, 2012). The capacity of solar pump is determined by peak daily water needs of crop and it thus determines the capital cost of irrigating various crops. It is found out that use of solar pumps being more economical to crops having higher revenues for per unit of peak water requirement (Campana 2015; Hossain et al., 2015).

Depth of water source also works as a determinant for using solar pump as discharge rate from a solar pump declines when the distance increases (Benghanem & Joraid, 2014). Crops which are been cultivated mostly in regions having lower water need higher capacity of solar pump. As the regions having lower water indicates comparatively dryer region solar radiation of those regions seems higher which makes usage of solar pump to be more effective on those regions as it influences the water discharge rate (Hossan et al., 2015).

The more the benefits derived from its use the more the willingness of farmers increases to use solar pumps for irrigation purpose (Pathanie et al., 2017). Thus solar products offer self-dependency (Kumar & Hundal, 2019).

Government Interventions on Solar Pumps

Government initiatives in any country are expressed in terms of supports, subsidies, and financial aids provided by the government (Pathania et al., 2017). Kevin (2013) asserted that government subsidies can have a good impact on the selling of solar energy products. As a result, efforts should be undertaken to give subsidies to promote solar products and raise awareness about environmental issues (Zongwei et al., 2018).

Furthermore, Carlos et al. (2018) noted that there should be a widespread advertising campaign to educate potential buyers about government subsidies and incentives. The previous study on environmental studies was founded on theoretical premises incorporating stakeholders, political economy, and shareholders' perspectives (Joshi and Rahman, 2015; Henriques and Sadorsky, 1999).

People who are deeply concerned about the environment believe that its preservation is the primary responsibility of the government (Farheen and Sehgal, 2018; Ministry of New and Renewable Energy, 2017). As a result, it is critical for the government to explain its role by providing enough subsidies, which will eventually have an impact on the adoption of solar energy-based products (Kumar et al., 2019; Horsky and Simon, 1983; Kalish and Lilien, 1983).

Subsidies provided by governments proportionately raise the sale of solar energy products. So in order to increase the use of solar energy more in the agricultural field, subsidies by governments need to be increased (Zongowi et al., 2018).

A large number of subsidies adopted by various developing country governments around the world increase the adoption of solar pumps (Kumar, 2020). Though many farmers are aware about solar pumps, but only a few are aware about subsidy schemes which work as a hindrance of vast use of solar pumps. Availability of other inputs like improved seeds and fertilizers seem to prolong the benefits of the use of solar pumps (You et al., 2011). Access to high quality inputs and market information also act as an important determinant for adopting solar irrigation pumps whereas unavailability of those reduces the amount of benefits (Gebregziabehr, 2012; Wakeyo & Gardebrock, 2017).

Methods

Study Sites

The study has been conducted in Jhenaidah district due to convenience. There are a number of households in Jhenaidah district who use solar pumps for the purpose of irrigation. The study has covered a total of four Upazilas of the Jhenaidah district. The Upazilas are: Jhenaidah Sadar, Horinadundu, Shailakupa and Kaliganj. Data have been collected from these Upazilas for the present study to understand the economics of solar powered irrigation pumps and also to assess its determinants.

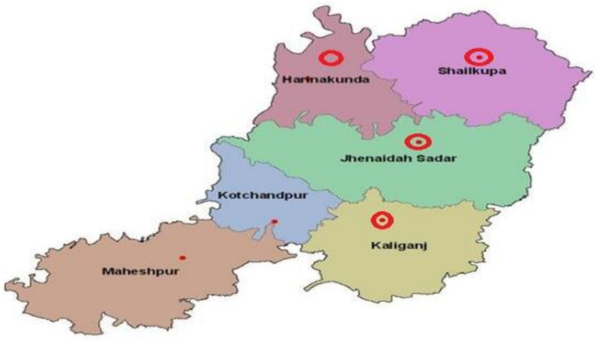

Figure 3.1. Layout of the Study Area

Data Collection and Analysis

In methodology part, the present has largely been based on primary data, collected through a field-survey conducted on four selected upazila: Jhenaidah Sadar, Harinakundu, Shailakupa and Kaliganj one of the most adopted solar power pump regions of the Jhenaidah Sadar for irrigation purpose, have been selected purposively to conduct the primary survey. A total of 150 households, have been selected randomly to conduct the survey. The primary survey was conducted using a structured questionnaire. After the collection of relevant information from the two selected villages, data have been analyzed mostly using descriptive analytical techniques such as ratio, percentage, graphs and figures, etc. Household characteristics of the sample respondents, their level of education, occupation, logit regression analysis for determinants of solar power irrigation, and profitability analysis for solar power irrigation.

Results and Discussion

Keeping in mind the very objectives of the current study that is to understand the economics of solar power irrigation system in Bangladesh and its determinants, the collected data have been analyzed using SPSS software. The data analysis part includes three sections such as: demographic and socio economic analysis, profitability analysis & regression analysis.

With this realization, it has been presented the descriptive statistics of the survey, which includes respondent characteristics and an idea on the type of different livelihood activities that are getting solar power pump adopted households. It has been tried to evaluate economic losses/damages and benefits shown in profitability analysis. The focuses has been given on the regression analysis that shows the determinants of solar pump irrigation by the respondent farmers.

The question of identifying possible remedial measures based on the outcomes from the surveyed upazilas which are supposed to have a better understanding about traditional (diesel) and alternative (solar) irrigation service as well as the remedial measures to solve/minimize negative consequences of the problem of traditional (diesel) in the area has been presented, on the other hand, comes up with an understanding on the various usefulness, that might be found in addressing the problem of existing traditional (diesel) pump related phenomenon.

Demographic and Socio Economic Analysis

The demographic and socio economic analysis has been using descriptive analysis. Under the descriptive analysis section of the present chapter, number of socio-demographic, educational, family income and expenditure, occupational, etc. has been considered for the descriptive analysis. The following tables have presented the summary on each of these points:

Income of the Respondents

Table 1. Income of the Respondents

Upazila	4000-10000 [Tk]	11000-20000 [Tk]	21000-30000 [Tk]	More than 30000 [Tk]	Total
Horinadundu	0	75	25%	0	100%
Jhenaidah Sadar	24.27%	51.46%	15.53%	8.87%	100%
Kaligonj	6.25%	68.75%	12.50%	12.50%	100%
Shailakupa	22.22%	51.85%	14.81%	11.11%	100%
Total	21.33%	54%	15.33%	9.33%	100%

Table 1, analysis of the income of the respondent's shows that 75% of the respondents of Horinadundu were from Tk.11000-20000 income group. In Jhenaidah Sadar upazila, the maximum respondents (51.46%) were from the income group of more than Tk.30000, whereas in Shailakupa and Kaliganj, the respondents mostly fall in the monthly income group of Tk.11000-20000.

Cultivable land of the respondents

Table 2. Cultivable land of the respondents

Upazila	0-50 [dec]	51-100 [dec]	101-500 [dec]	More than 500 [dec]	Total
Horinadundu	0	25%	75%	0	100%
Jhenaidah Sadar	22.33%	17.48%	57.28%	2.91%	100%
Kaligonj	6.25%	18.75%	62.50%	12.50%	100%
Shailakupa	44.44%	29.63%	25.93%	0	100%
Total	24%	20%	52.67%	3.33%	100%

Table 2, shows 75% of the respondents of Horinadundu upazila, 57.28% respondents of Jhenaidah Sadar upazila and 62.5% of the respondents from Kaligonj upazila had cultivable land between 101-500 decimal, while 44% of the respondents from Shailakupa upazila had cultivable land between 0-50 decimal.

Food production in last one year

Table 3. Food production in last one year

Upazila	200-1000 kg	1001-1500 kg	1501-2000 kg	2001-2500 kg	More than 2500 kg	Total
Horinadundu	0	25.00%	25.00%	0	50.00%	100%
Jhenaidah Sadar	34.95%	17.48%	13.59%	5.83%	28.16%	100%
Kaliganj	31.25%	12.50%	6.25%	0	50%	100%
Shailakupa	18.52%	37.04%	7.41%	11.11%	25.93%	100%
Total	30.67%	20.67%	12.00%	6.00%	30.67%	100%

Table 3, presents the food production capacity of the four upazilas in the last year and it shows that most of the respondents from Horinadundu (50%) & Kaliganj (50%) produced more than 2500 kg. 37% of the respondents Shailakupa produced between 1001-1500 kg. 34.95% of the respondents from Jhenaidah sadar produced between 200-1000 kg food crops. Productivity is lower in Jhenaidah and higher in Horidundu and Kaligonj upazila.

Perception on cost of solar pump compared with diesel pump

Table 4. Perception on cost of solar pump compared with diesel pump

Upazila	**Very lower cost** [Tk]	**Lower cost** [Tk]	**Same as diesel pump** [Tk]	**Slightly costly** [Tk]	**Very high cost** [Tk]	**Total**
Jhenaidah Sadar	9.76%	20.73%	2.44%	23.17%	43.90%	100%
Kaliganj	0	0	6.25%	6.25%	87.50%	100%
Shailakupa	0	12.00%	8.00%	44.00%	36.00%	100%
Horinadundu	0	0	0	0	0	0
Total	6.50%	16.26%	4.07%	25.20%	47.97%	100%

Table 4 represents that most of the respondents believe solar pump are costlier than diesel pump. 43.90% of the respondents from Jhenaidah, 87.50% from Kaligonj, 36%of Shailakupa believe solar pump is very costly. 44% of the respondents Shailakupa thinks solar pumps are slightly costly.

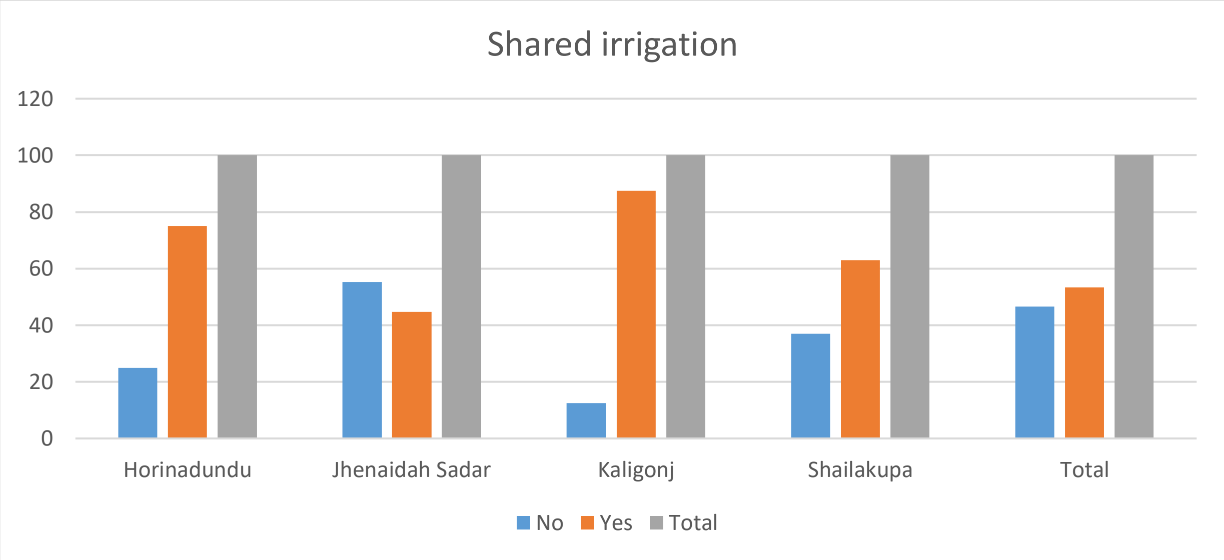

Figure 1. Respondents in Shared Irrigation

Figure 1 presents the overall situation of shared irrigation. Jhenaidah Sadar had the highest percentage of shared irrigation facilities compared to the three other upazilas. Share of the respondents from Kaliganj, Shailakupa and Horinadundu in shared irrigation was found to be 17.50%, 21.25% and 3.75%, respectively.

Profitability Analysis

Benefit-cost ratio helps to take the decision to adopt a new establishment. In this study, the benefit-cost ratio is considered to depict the feasibility of a household to adopt solar pump over diesel pump for irrigation. Due to lack of time and budgetary resources, the study could not include estimation of environmental benefits. The benefits thus being considered in case of opportunity cost is the cost of diesel pump for irrigation. The segment of costs and benefits are kept homogenous such as, cost of purchasing, maintenance and irrigation (based on cost of irrigation in per decimal of land and total cultivable land). Consider the following table:

Table 5. Profitability Analysis

Cost (Solar Pump) in BDT		**Total Cost**	**Benefit Cost Ratio**
Cost of purchasing	14,81,50,000	17,40,77,846	0.277093
Cost of Maintenance	2,91,700		
Cost of Irrigation	2,56,36,146		
Benefit (Diesel Pump Cost) in BDT		**Total Benefit**	
Cost of purchasing	42,76,000	4,82,35,814	
Cost of Maintenance	14,60,100		
Cost of Irrigation	4,24,99,714		

Table 5, shows benefit-cost ratio found to be 0.2771 implicates that, if households adopt solar pumps for irrigation compared to diesel pumps, the cost outweigh benefit. Therefore, at the present market situation, adopting solar pumps is less likely feasible for the farmers due to its higher cost.

In such cases, government can increase the amount of subsidy to purchase solar irrigation pumps considering its environmental cleanliness. If the solar pumps are produced within the country, the cost of purchasing and maintaining solar pumps for irrigation is likely to decrease. To encourage the local producers, government can reduce the import tariffs on the raw materials of producing solar pumps and give facility in the economic zones to produce solar pumps. Thus the solar pumps may be available within the reach of the people.

Logistic Regression Analysis

As the dependent variable of this analysis is binary, the study has adopted using logit regression analysis technique for convenience with robustness. The regression model conducted 4 times iteration with 9 degrees of freedom and the value of psedu R^2 was 0.3325.

Table 6. Determinants of using solar pump

Variables	Logit Regression	Odds Ratio
Age	-0.00413	0.996
	(0.0149)	(0.148)
Income	0.0000341	1.000034
	(0.0000209)	(0.0000209)
Household Size	0.168*	1.183*
	(0.100)	(0.1186)
Cultivable Land	-0.00119	0.9989
	(0.00183)	(0.0018)
Source of Water for Irrigation within 200 meter	1.227***	3.41***
	(0.415)	(1.417)
Share Irrigation	-1.662***	0.1898***
	(0.458)	(0.087)
Perception on Improved Production	2.490***	12.06***
	(0.614)	(7.4098)
Current year yield	0.0000454	1.000045
	(0.000078)	0.000078
Constant	-4.004***	
	(1.428)	
Observations	150	

Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Using logit regression analysis, the study found that elder respondents were less likely in using solar pumps for irrigation compared to that of the young respondents. According to the odds ratio, the likelihood of elder people of using solar pumps is 1% less than that of the younger people. Usually, elderly citizens have apathy to use upgraded and different types of technologies and the results are reflected here. In addition, the elderly people are accustomed to diesel water pumps, rainwater as well as water from other sources for irrigation over a long period of time that made them inelastic to adopt a new and different technology.

Affluent respondents are more likely to adopt solar pumps than that of the less affluent respondents. However, the magnitude of the difference is lower and the result is not statistically significant. The log likelihood of affluent people to use solar pump was estimated to be 0.0034% more than that of the others. That implies, being affluent does not necessarily proliferate the enthusiasm to use solar pumps.

The more the size of a household, respondents are more likely to use solar pump technologies. Odds ratio illustrates that, bigger households were 18% more likely use solar pumps compared to that of smaller households. This result is significant at 10% statistical level of significance. The bigger the household size, they have more modality (in terms of human resource) to try different things, gather experience and adopt the efficient one carefully. Moreover, bigger households always focus on efficiency in terms of yield that leads them to use solar pumps for irrigation.

Analysis found that the more the household possess cultivable land; they are less likely intended to use solar pumps for irrigation. The log-likelihood of using solar pumps with higher cultivable land owner is 1% less than that of their counterpart. However, the likelihood is relatively small and the result is not statistically significant in this sample. There can be further scopes for future studies to identify the relationship between these two variables.

If the source of water for irrigation is within 200 meters, respondents are more likely to use solar pumps. In other words, respondents with solar pumps found it convenient to plant the solar pumps irrigation within the short range of distance. This might be another reason for the apathy of the higher land owner in case of using solar pumps. The estimated odds of the respondents who have access to water for irrigation within 200 meters are found to be 3 times more than that of others. It depicts that; solar pumps may be more likely convenient if the water sources are available nearby. In other words, people found it convenient to install solar pumps for irrigation near their cultivable lands. This result is statistically significant at 1% level of significance.

People who were found to share irrigation services for cultivable lands might found it difficult to use solar pumps. May be, it is difficult to turn too many people amenable to use solar pumps in case of irrigation or people have already established their irrigation planning and materials before thinking of solar pumps. Results show that, people who share the irrigation are less likely to use solar pumps. The log-likelihood of shared irrigation respondents to use solar pumps is 81% less than that of their counterparts. This result is significant at 1% statistical level of significance.

Positive perceptions towards the improved production have significant influence on using solar pumps. Analysis shows that, people who perceived that using solar pumps for irrigation would engender the production are more likely to use solar pumps. The odds are 12 times more than that of others with 1% statistical level of significance. In fact, using solar pumps indirectly impact on production. It may reduce the marginal and variable costs of production that would work as catalyst in case of rate of return of production.

The argument gets validity, while examining the influence of current year yields on using solar pumps. From the logit regression analysis the study found that, respondents with better yields are more likely to use solar pumps. However, the result is not statistically significant. According to odds ratio, the probability of using solar pumps for irrigation is 0.000045% higher for those who experienced higher yields compared to their counterparts.

Conclusion

The study collected primary data from the Jhenaidah district, a southern district of the country. The respondents were involved in agricultural activities and were also homogenous in terms of demographic characteristics. Among the respondents, some of them used regular pumps for irrigation and some other used the solar pumps. It was observed that, many of the respondents shared the costs and management of irrigation for cultivation with their peer farmers. The usage of solar pump is yet to be more acceptable by the local people. The 1st aim of the study is to understand the economics of using solar energy for irrigation. Basically, economic analysis focus on the benefit-cost ratio for profitability analysis and also demographic and socio economic analysis. According to 2nd aim of the study, to the identify determinants of using solar pumps. The study thus used a benefit-cost ratio to conduct the profitability analysis. On the contrary, logit regression analysis was conducted to identify the determinants of using solar pumps for irrigation. Profitability analysis found that the estimated benefit-cost ratio 0.2771, implying that, if households adopt solar pumps for irrigation compared to diesel pumps, the cost would outweigh than the benefit. Therefore, at present market situation, adopting solar pumps is less likely feasible for the farmers due to its higher cost.

According to logit regression analysis, study found that household size, source of water for irrigation within 200 meters, shared irrigation, and perceptions on improved production significantly influenced the usage of solar pumps for irrigation among the surveyed farmers. The elder people are less likely to adopt the solar pumps compared to that of the younger ones. It implies that any intervention from government or other parties regarding solar pumps can focus more on younger people. Family size also matters in case of usage of solar pumps, where higher family member households usually prefer using solar pumps. Considering the fact of the volume of the population, it is assumed that, Bangladeshi people are more likely to accept the solar pumps in terms of irrigation. However, in case of shared irrigation, it becomes difficult for everyone to change a planned establishment and switch on to solar pumps. Based on the findings and conclusion, the study can recommend the following things:

- Higher household sized family is more likely adopt the solar pumps.
- Farmers who already have adopted diesel-run pumps required more government subsidy to transform solar into solar pump irrigation.
- Those who use shared irrigation system are reluctant to use solar pumps. Govt. subsidy can also proliferate their enthusiasm to use solar pumps.
- It is very important to engender the awareness of people. Because when they know that, using solar pump results for better yield, people are more likely motivated in using solar pumps.

Recommendations

The estimated cost-benefit ratio was found to be 0.2771, implying that, if households adopt solar pumps for irrigation compared to diesel pumps, the cost would outweigh than the benefit. Therefore, at present market situation, adopting solar pumps is less likely feasible for the farmers due to its higher cost. Considering these realities and based on the research findings the following specific suggestions can be made:

- Government can increase the amount of subsidy to purchase solar irrigation pumps considering its environmental cleanliness.
- If solar pumps are produced within the country, the cost of purchasing and maintaining solar pumps for irrigation would be more likely to decrease. To encourage the local producer, the government can reduce the import tariffs of the raw materials of producing solar pumps and give facility in the economic zones to produce solar pumps. Thus the solar pump may be within the reach of the people.

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Abbreviations

BDT	Bangladeshi Taka
Tk	Taka
Kg	Kilogram
Dec	Decimal
SWP	Solar Photovoltaic Water Pumping
PV	Photovoltaic Panels
AC	Alternating Current
DC	*Direct Current*
HYV	High Yielding Varieties
SREDA	Sustainable and Renewable Energy Development Authority
IDCOL	Infrastructure Development Company Limited
BERD	Office of Building Energy Research and Development

MNRE	Ministry of New and Renewable Energy
GDP	Gross Domestic Product
FAO	Food and Agriculture Organization of the United Nations
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
SDGs	Sustainable Development Goals

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APPENDIX

Table 1. Expenditure of the respondent households

Upazila	4000-10000 [Tk]	11000-20000 [Tk]	21000-30000 [Tk]	More than 30000 [Tk]	Total
Horinadundu	0	75	25	0	100
Jhenaidah Sadar	34.48	48.28	13.79	3.45	100
Kaliganj	31.25	50	6.25	12.50	100
Shailakupa	28.578	57.14	0	14.29	100
Total	30.36	51.79	10.71	7.14	100

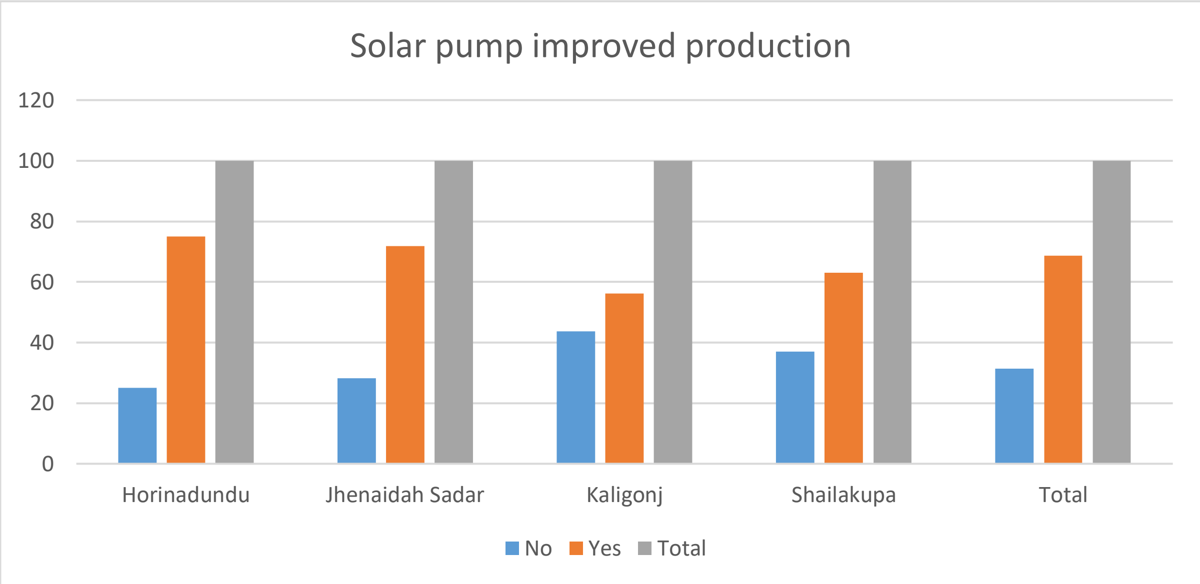

Figure 1. Perceptions of people on solar pump's improved production capacity

Table 2. Common natural calamities in the area (multiple responses)

Common natural calamities	**Horinadundu**	**Jhenaidah Sadar**	**Kaliganj**	**Shailakupa**
Heavy rainfall	0	41.58	0	55.56
Less sunshine	0	37.62	0	59.26
Flush flood	0	3.96	6.25	0
Storm	100.00	82.18	100.00	66.67
Lightening	100	86.14	93.75	85.19

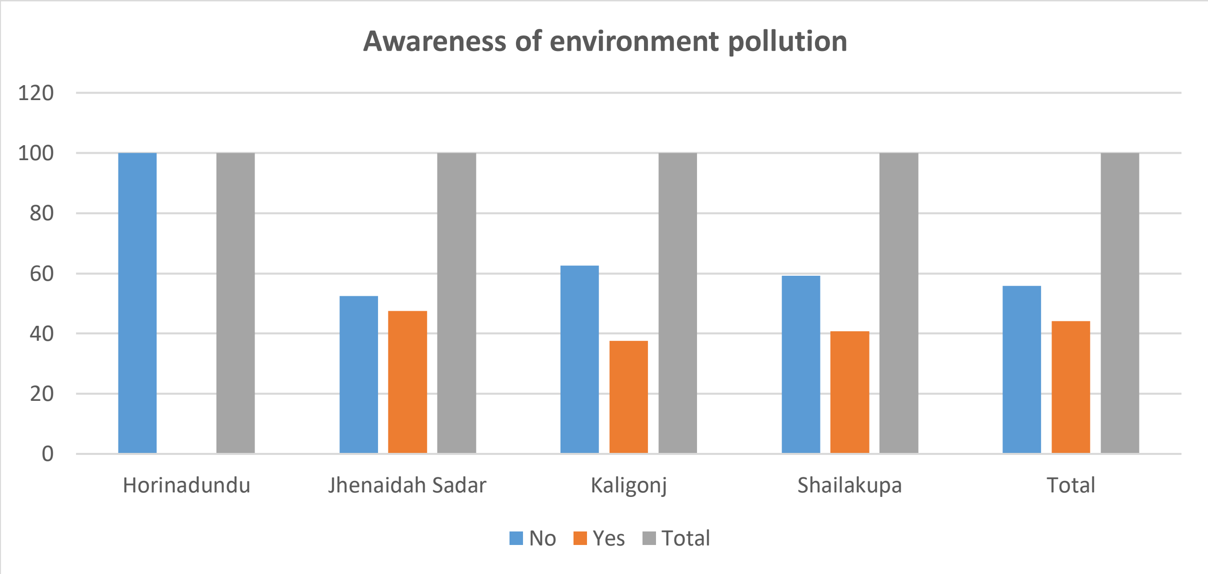

Figure 2. Awareness of environmental pollination

Table 3. Factors effecting performance of solar pump (multiple responses)

Factors effecting performance of solar pump	Jhenaidah Sadar	Kaliganj	Shailakupa	Horinadundu
Heavy rainfall	90.00	100.00	92.44	0
Less sunshine	77.50	93.75	82.35	0
Flush flood	32.50	0	25.21	0
Storm	62.50	6.25	51.26	0
Lightening	28.75	0	24.37	0

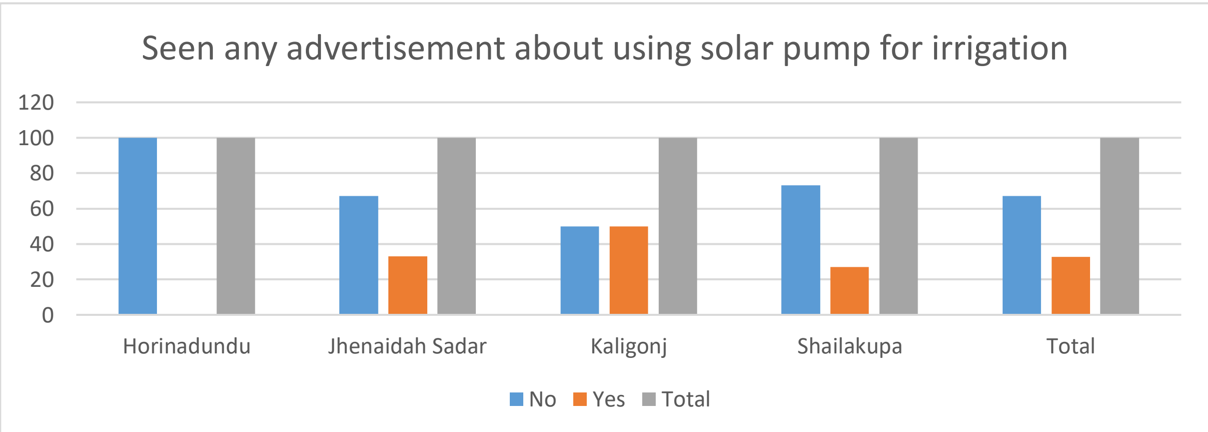

Figure 3. Seen any advertisement about solar power irrigation