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Use of solar powered irrigation and its impact on rice cultivation

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ABSTRACT

Solar pump irrigation (SPI) is considered as a climate-smart adaptation strategy. This irrigation system is trying to expand throughout the country in rice cultivation. In this context, the objectives of the study were to assess the extent of use of SPI, to determine the impact of using SPI and the factors influence the use of SPI. The study was conducted in Chuadanga district and Jhenaidah District in Bangladesh. Data were collected from randomly selected 298 farmers in a face to face interview followed by a structured questionnaire. Descriptive statistics such as mean, standard deviation, percentage, frequency and inferential analysis such as binary logistic regression which is popularly known as logit model and t-test were run to interpret the data. The surveys revealed that the majority of the farmers were non-users of SPI despite positive impact of using SPI. A little more than one-third (37.9%) of the farmers used SPI and it was more profitable to use SPI. The Logit model explored that farmers level of education, farming experience, farm size and extension contact significantly influence farmers use of SPI. The public and private sectors of Bangladesh should establish more SPI in various districts and the extension agents should motivate farmers to use this climate smart adaptation strategy for sustainable rice production.

Keywords: *Solar irrigation, rice cultivation, impact, profitability, logit model.*

1. Introduction

Irrigation systems driven by solar energy are especially referred to as solar-powered irrigation (SPI) systems. It entails employing photovoltaic (PV) panels, sometimes referred to as solar panels, to capture solar energy and use it to create electricity. Afterwards, this electricity powers irrigation water pumps, offering a dependable and sustainable power source for agricultural water management. Particularly in areas with plenty of sun radiation, rice farming has come to focus on SPI as a viable and economical option. Over the last few years the use of SPI for irrigation in rice farming is gradually increased [1].

Solar pumps are being utilized more often in nations like Bangladesh, Thailand, China, and India to address issues with the cost and availability of energy for conventional pumps. The potential of SPI in rice production has been acknowledged by the International Rice Research Institute (IRRI). [2] found that SPI can raise crop yields by as much as 50%, significantly enhancing food security and rural livelihoods. The use of SPI has grown in popularity as a more economical and environmentally friendly option to conventional irrigation systems that depend on grid energy or fossil fuels. [3] evaluated the economics and performance of diesel and solar pumps in Bangladesh and discovered that solar pumps were more economical to use and required less maintenance than diesel pumps. In addition to being more dependable and having a greater discharge rate than diesel pumps, solar pumps also have less downtime from malfunctions. In a different research, [4] evaluated the energy and water consumption efficiency of solar and electric pumps in India and discovered that solar pumps performed better overall and also found that solar pumps had lower maintenance costs and were more reliable than electric pumps, with less downtime due to power outages. Solar pumps has higher energy efficiency than diesel pumps, with a lower energy consumption per unit of water pumped along with lower operating costs and greenhouse gas emissions than diesel pumps in China [5]. Considering the environmentally friendly nature of SPI, the technology is treated as climate smart agricultural practice.

Overall, solar pumps offer several advantages over traditional pumps, including lower operating and maintenance costs, higher reliability, and improved energy efficiency. Solar energy is known as one of the most secure and low-cost sources of electricity, and in a country such as Bangladesh with abundant sunshine for most of the year, sourcing energy from the sun rays should be a fittingly beneficial experience for irrigation purposes. Since the need for water is the highest on hot sunny days, this technology is an obvious choice [6].

In Bangladesh, agriculture is responsible for 5.3% of the total energy consumption of the country where diesel (75%) and electricity (21%) are used as major fuel in operating farming machinery and Renewable Energy Sources (RES) share is 4% only [7]. SPI as a part of renewable energy is used to reduce traditional irrigation methods. Research on SPI in Bangladesh focused on various areas to further understand its potential, optimize its implementation, and address specific challenges faced in the context of the country. The present study focused on economic impact of using solar pump irrigation by the rice growers and the factors that influence rice growers use of SPI. In some areas of Chuadanga and Jhenaidah District, Solar-powered irrigation is already being used in providing irrigation for rice cultivation. Thus the present study, entitled Determinants of Using SPI in Rice Cultivation has been undertaken to achieve the following objectives-

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1. To assess the extent of using solar pump irrigation among the rice farmers;
2. To determine the impact of using solar pump irrigation in rice cultivation and
3. To identify the key factors affecting farmers' use of solar pump irrigation.

2. Methodology

2.1 Study area

The research was carried out in Maheshpur and Alamdanga Upazila under Jhenaidah and Chuadanag District respectively. Two villages of Swaruppur union under Maheshpur Upazila of Jhenaidah district and three villages of Ailhus, Khashkoura and Dauki Union of Alamdanga Upazila under Chuadanga district were finally selected for the study. Thus, the study covered five villages under four unions of two upazilas from two districts. The study area were purposively selected which means existence of solar pump irrigation in rice farming.

2.2 Population and sampling

The researcher with the help of Sub-Assistant Agriculture Officer (SAAO) and Upazila Agriculture Office (UAO) under Maheshpur and Alamdanaga Upazila collected lists of farmers from the selected five villages. The lists contained a total of 1986 farmers, including 509 farm family heads from Kushadanga village, 212 from Hanifpur village, 386 from Ailhus village, 414 from Khashoura village and 465 from Badumazi village of two districts. The size was treated as population for the study. To conduct the study, a representative sample of 298 farmers was selected, which represents 15% of the total number of farmers (population). The sample size was drawn proportionately from the villages which mean equal portion of farmers (15%) has been selected from the total farmers in each village. Finally, to collect data from these farmers a simple random sampling employed.

Table 1: Population and sample for the study

Name of District and Upazila	Name of Union	Name of villages	Population size	Sample size
Jhenaidah (Maheshpur)	Swaruppur	Kushadanga	509	76
		Hanifpur	212	32
Chuadanga (Alamdanga)	Ailhus	Ailhus	386	58
	Khashkoura	Khashkoura	414	62
	Dauki	Badumazi	465	70
Total	4	5	1986	298

2.3 Collection of data

Both primary and secondary data were collected for the study. Secondary data were collected from the respective organizations and primary data were collected from the farmers through a face -to-face interview. The interview was conducted following a structured questionnaire. The questionnaire consisted three parts. Farmer's socio-economic characteristics were highlighted in the first part of the questionnaire. Their use of solar pump irrigation was mentioned in the second part of the questionnaire. The third and last part of the questionnaire covered cost from conventional irrigation system and solar pump irrigation. The data were collected by the expert enumerator. Before collecting data from the farmers, the researcher provided training to the enumerator. Both closed and open form questions were put in the questionnaire.

The study considered two types of variables such as independent variables and dependent variable. Farmers' selected socio-economic characteristics were considered as independent variables or factors in the study while their use of solar pump irrigation was considered as dependent variable for the study. The measuring techniques of these variables are shown in the Table 2.

Table 2: Measuring techniques of independent and dependent variables for the study

Variables	Type	Measuring techniques
Independent variables		
Age	Continuous	Age of farmers at the time of interview in years
Education	Continuous	1 for 1 year of schooling of the farmers
Family size	Continuous	Total members of a farmers household
Farming experience	Continuous	1 for 1 year of experience in farming
Annual income	Continuous	Total family income from agriculture and non-agricultural sources and expressed in thousand BDT.
Total farm size	Continuous	Total cultivated land in acre
Rice cultivation area	Continuous	The cultivated land under rice cultivation in acre
Land ownership status	Binary	1 for land owner and 0 for others
Credit access	Binary	1 if have credit access and 0 for others
Extension contact	Continuous	Number of contact with the extension agent per crop season
Dependent variable		
Use of SPI	Binary	1 if use solar pump irrigation and 0 for others

2.4 Analysis of data

After collection of data they were processed and coded for analysis. Descriptive and inferential analysis was made to interpret the data. Some common descriptive statistics such as mean, standard deviation, range, frequency, percentage, t-test were done to achieve objective 1 and 2. Binary logistic regression, which is popularly known as logit model was applied to achieve objective 3.

3. Results and Discussion

3.1 Farmers' use of solar pump irrigation in rice cultivation

In the question of using SPI, the farmers' were categorized into two groups such as users and non-users. It was the dependent variable of the study and was measured as 1 for user of SPI and 0 for non-user of SPI. So, the range was 0 to 1. The average score for the use of SPI was 0.38 and standard deviation was 0.48. The categories along with their number and percentage are shown in the Table 3.

Table 3: Farmers distribution based on using solar pump irrigation (SPI)

Farmers category	Number	Percentage (%)	Mean	Standard deviation
User of SPI	113	37.9	0.38	0.48
Non-user of SPI	185	62.1		
Total	298	100		

According to the data presented in Table 3, the majority of respondents (62.1 percent) do not use SPI in rice cultivation. On the other hand, a little more than one third (37.9 percent) of the respondents used SPI to irrigate their land. The study found that most farmers are non-users, possibly due to the unavailability of solar pumps near their farmland or because they did not find it more beneficial than traditional irrigation methods. However, during the survey, researchers noted a positive attitude from most farmers who were interested in using SPI. Unfortunately, due to insufficient capacity of current solar pumps and inadequate availability of solar pumps as per the amount of land, fewer farmers could use SPI, and most farmers remained underprivileged with respect to SPI.

3.2 Impact of using solar pump irrigation in rice cultivation

The farmers of the study area were divided into two groups with regards to the use of SPI in rice cultivation. Some of them use SPI where others use conventional irrigation system (fossil fuel based irrigation system). The study collected data on the irrigation cost from both type of farmers. The result of the t-test regarding comparing the irrigation cost of both farmers is shown in the Table 4. It is observed from the Table that there is a significant mean difference between the farmers who use SPI and who do not use SPI. The mean cost for the SPI users are significantly lower than the average cost for the conventional irrigation users. This means use of SPI for irrigation is relatively cheaper than the traditional system. Thus, considering constant to other cost parameters of rice cultivation, it can be said that the farmers' who use SPI will get more profit than the farmers who are engage with traditional irrigation system.

Table 4: Independent sample t-test showing the difference between SPI user and non-users cost for irrigation

Item	Mean	Mean difference	t-value	sig
Cost for using SPI	21.08	17.85	2.943	0.004
Cost for using conventional	33.0			

3.3 Key factors affecting farmers' use of solar pump irrigation

To identify the key factors affecting farmers' use of SPI, binary logistic regression analysis was done. Here the preliminary factors were farmers 10 selected characteristics such as age, education, family size, annual income, farming experience, farm size, rice cultivation area, land ownership status, credit access and extension media contact. The logistic regression analysis identified the key factors from these selected factors. However, before run the analysis, a description of the selected characteristics or factors was presented below.

The categories, mean, percentage, number, and standard deviation of farmers characteristics or factors are shown in the Table 5. It is observed from the Table that majority of the farmers (80.2%) were young to middle aged which indicates active aged farmers in the study area. The literacy rate (79%) of the farmers in the study area was higher than the national average of 75% [8]. Likewise education, average household size (5) was also higher than the national average of 4.3 [8]. Majority of the farmers had long experience in farming with moderate farm income. Majority of the farmers were the owners of small and medium farm and they used a good amount of their land for cultivating rice. Most of the farmers were land owners, having low access of extension contact and no credit access facility (Table 5). However, to identify the significant factors influence the use of Solar Pump Irrigation among these characteristics or factors, the study applied binary logistic regression model (Table 6).

Table 5: Salient features of farmers' selected characteristics or factors (N=298)

Farmers' characteristics	Category	Number	%	Mean	SD
Age (years)	Young (up to 35)	74	24.8	42.93	8.84
	Middle (36 to 50)	165	55.4		
	Old (above 50)	59	19.8		
Education (score)	Illiterate (0)	63	21.1	5.74	3.76
	Primary (1 to 5)	73	24.5		
	Secondary (6 to 10)	148	49.7		
	Above secondary (>10)	14	4.7		
Family size (number)	Small (up to 4)	101	33.9	5.20	1.39
	Medium (5 to 7)	183	61.4		
	Large (above 7)	14	4.7		
Farming experience (years)	Low (up to 17 years)	138	46.3	19.80	9.14
	Medium (17 to 34 years)	131	44		
	High (>34 years)	29	9.7		
Annual income (000'BDT)	Low (up to 170)	109	36.6	218.22	87.68
	Medium (> 170 to 340)	172	57.7		
	High (> 340)	17	5.7		
Total farm size (acre)	Small (up to 2.5)	165	55.2	5.40	4.24
	Medium (>2.5 to 7.5)	99	33.3		
	Large (> 7.5)	34	11.5		
Rice cultivation area (acre)	Small (up to 2.5)	244	81.9	3.50	2.96
	Medium (> 2.5 to 7.5)	49	16.4		
	Large (> 7.5)	5	1.7		
Land ownership status (score)	Land owner (1)	169	56.7	0.56	0.51
	Tenants (0)	129	43.3		
Credit access (score)	Yes (1)	94	31.5	0.32	0.46
	No (0)	204	68.5		
Extension contact (number per season)	No (0)	58	19.5	2.0	1.35
	Low (up to 3)	197	66.1		
	Medium (4 to5)	43	14.4		

Table 6: Binary logistic regression showing the contribution of farmers' characteristics/factors on the use of SPI

Farmers Characteristics	B	S.E.	Wald	Sig.	Exp(B)
Age	.014	.029	.242	.623	.014
Education	139	.041	11.673	.001	1.870
Family size	-.231	.125	3.385	.066	.794
Farming experience	.671	.029	6.131	.013	1.931
Farm size	.868	.166	27.217	.000	2.383
Rice cultivation area	-1.334	.251	2.177	.090	.263
Land ownership	-.022	.407	.003	.957	.978
Credit access	-1.243	.356	2.175	.098	.289
Extension contact	.259	.184	1.982	.009	1.295
Annual income	-.001	.002	.636	.425	.999

*– Loglikelihood value is 309.144, The Omnibus test of model coefficient is 86.402***

Out of farmers 10 selected characteristics, four namely education, farming experience, farm size and extension contact showed significant contribution on the use of SPI. Out of these 4 significant factors, farming experience was significant at 5% level of significance and rest 3 significant factors (education, farm size and extension contact) were significant at 1% level of significance. On the other hand, the rest 6 characteristics or factors namely age, family size, rice cultivation area, land ownership status, credit access and annual income don't show any significant relationship with the use of SPI.

The Omnibus test of model coefficient is 86.402. The value is significant at 1% level of significance. The – Loglikelihood value is 309.144 which are different from zero. The Cox and Snell R^2 and Nagelkarke R^2 were .252 and .343 respectively. The value of these parameters showed that the analysis is valid.

The contributing relationship between education and farmers use of Solar Pump Irrigation (SPI) was significant and positive. This means that the higher the farmers educational level the higher the probability of use SPI. The Exp (B) value indicates education helps to increase about 2 times probability of use of SPI. This may be due to the fact that education broadens individual's knowledge and outlook, which might have effect to take right decision regarding adoption of a technology like SPI. The finding is in line with the findings of [9], [10] and [11]. It is therefore, recommended that initiative to educate farmers might help to increase the users of SPI.

The use of SPI was also significantly influenced by farmers' length of farming experience. The positive coefficient between these two phenomena indicates higher experience helps farmers to take decision for using SPI. The farmers having long experience in farming were positive to accept SPI than the farmers having lower experience in farming. The Exp (B) value indicates that farmers having long experience had two times higher probability to use SPI than the farmers who have less experience in farming. This may be due to the fact that experience enriches a person for decision making by comparing among various technologies. To increase the number of SPI users it is better to contact by the extension agent specially the Sub Assistant Agriculture Officer (SAAO) more with the farmers having less experience in farming.

Farm size showed highly significant and positive contribution on the use of SPI. The farmers who had more farm size showed more interest to use SPI. The Exp (B) value indicates the farmers who have large farm size have more than 2 times higher probability to use SPI than the farmers who have a small farm size. This might be due to the fact that the farmers having large farm have more understanding and risk taking capacity regarding use of technology. [12] and [13] experienced that there was a positive and significant relationship between farm size of the farmers and the use of improved agricultural technology.

Finally, there was a significant and positive relationship found between extension media contact and farmers' use of SPI. The findings is similar with the studies of [9] and [14] who found that extension contact played a significant role to take positive decision regarding the use of SPI. Extension contact helps farmers to understand the profitability of a technology and building their capacity to use that technology. Therefore, the extension agent should strengthen their activities to motivate farmers for using SPI. There is a poor ratio between extension agent (SAAO) and farmers. To overcome the barrier, the SAAO can sit their office for a specific time period. Moreover, use of Mobile phone for solving agricultural problem may also be helpful to overcome the barrier.

4. Conclusion and recommendations

As a part of renewable energy, solar pump irrigation (SPI) is considered as climate smart adaptation technology. This study revealed that the farmers who used SPI expensed less than the farmers who used traditional irrigation system. This means use of SPI is more profitable than the traditional irrigation system in rice cultivation. However, due to limited area coverage by SPI, the majority of the farmers are beyond to use the technology. As there have scarcity of electricity in the crop season, we should welcome solar based irrigation system. The study found that farmers' use of SPI was influenced by their higher level of education, long farming experience, large farm size and higher extension contact. The public and private sectors are implementing SPI throughout the country. The initiatives are not adequate in compare to farmers demand. Therefore, still there have an ample scope to expand the technology among the farmers for sustainable rice production. However, to increase the users SPI, following recommendations have been made.

- More public and private sectors should come forward to establish SPI in the area where rice cultivation is high.
- The extension agent should strengthen their activities to motivate farmers for using SPI for rice cultivation.
- Bangladesh Agricultural Development Corporation (BADC) should establish more SPI in different district.
- The government should encourage the private sectors and give incentives for establish SPI.
- The SAAO should contact more with the farmers with lower educational level, smaller farm size and less experience in farming to encourage the use of SPI.

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