Journal of Environmental Science 11 (2024) 01-07

IES University of Rajshahi

Journal of Environmental Science

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Factors Affecting Adoption of Solar Irrigation Pumps for Sustainable Agriculture in Northern Bangladesh

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ARTICLE INFO

***Keywords*:**
Solar irrigation pumps (SIPs),
Groundwater irrigation,
Relative price of energy,
social capital,
Adoption factors.

ABSTRACT

In Bangladesh, insufficiency of surface water leads the farmers to rely on ground water irrigation for crop agriculture. However, the irrigation system in Bangladesh is mostly based on diesel and electricity utilization, which increases costs of production and pollutes the environment. Therefore, some farmers have been found to use solar irrigation pumps to lift ground water for irrigation as a measure of agricultural sustainability. The objective of this research was to identify the factors that affected adoption of SIPs by farmers in the Northern region of Bangladesh. For this purpose, data were collected from 206 farm households of two districts of Northern Bangladesh namely, Thakurgaon and Dinajpur. Bivariate logistic regression model has been employed to analyze the collected data. Estimation results revealed that education, experience, peer relation, and relative price of energy had positive and significant effect on farmers' decision to adopt SIPs. The variables namely, training, income and social capital did not affect the SIP adoption decision of the farmers. These findings highlight the need for focused interventions and policy measures in terms of education, farmer peer networking, and affordable pricing to expand solar energy use for sustainable agriculture in the Northern Bangladesh.

1. Introduction

Bangladesh is primarily an agriculture-based economy, and agriculture sector has been contributing significantly to maintain economic growth of the country. It also plays essential economic roles in poverty reduction and maintenance of food security for the people of the country**.** In the fiscal year 2020, the contribution of agriculture sector to the GDP of Bangladesh is 12.6%, and around 42% of the labor force of the country is directly or indirectly involved in this sector (BBS, 2022).Agriculture creates majority of employment opportunities and ensures sustainable livelihood through providing employment and source of income of the people. Agriculture also provides significant role in the economy through supplying raw materials for the industrial sector, and earning foreign currency by agricultural exports. Agricultural households cultivate a variety of commodities, including local and hybrid paddy, wheat, maize, jute, minor cereals, vegetables, spices, etc. (BBS, 2019). Northern region of Bangladesh produces a significant proportion of these agricultural products.

However, the global community is becoming increasingly concerned about the detrimental effects of intensive agricultural practices. Environmentalists, ecologists, policymakers, researchers and farmers- all

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Receive 27 June 2024; Revised Received 17 September 2024; Accepted 06 November 2024;
Available Online 12 December 2024;
Published by Institute of Environmental Science, University of Rajshahi.

arealso concerned about the effects of intensive agriculture on the environment (Hossain & Islam, 2019). Modern agriculture is basically dependent on ground water irrigation system, which uses fossil fuel combustion and thus contributes to various environmental problems including air pollution,water pollution, broad-scale climate change and global warming, and the potential extinction of particular plant and animal species (Tasneem et al., 2020; Guta, 2018; Lim et al., 2020). Moreover, fossil fuel-based irrigation system leads to release of greenhouse gases that accelerate climate change (Khalaf et al., 2015). Another concern arises about the dependence on fossil fuel is that in the next few decades, fossil fuels is expected to be of short supply in the near future, and this consideration warrants finding of alternative energy sources which would meet the future needs but would not harm the environment (Tasneem et al., 2020).

Due to increasing energy needs and environmental problems with non-renewable sources, it is required to look for alternate energies (Rezvani et al., 2022). Using renewable energy can be a suitable solution in this situation as use of renewable energy is a significant component of sustainable agriculture, which refers to the ongoing production of agricultural commodities without causing harm to the wealth of future generations. It offers a practical way to address the fundamental and practical challenges associated with the ecological production of food and fiber (Lal, 2008).Irrigation is one of the important components of agricultural cultivation and its management is very crucial at the field level. There are many kinds of irrigation systems dissel based irrigation, electricity based irrigation, solar based irrigaiton, surface water based irrigation, etc. It is observed by existing researchers that increasingaccess to cost-effective, readily available, and environmentally friendly energy is crucial to economic success (Maqbool et al., 2020). Because of the factors mentioned above, renewable energy sources have emerged as a formidable competitor of fossil fuel-based energy sources for meeting power demands in the short and long term. Moreover, these sources are abundant and environmental friendly (Tasneem et al., 2020). With facing significant disputes regarding nuclear power plants, South Korean experts considered solar energy as one of the most promising renewable energy sources that is available in nature, and is secured for the environment and the economy (Kim et al., 2014).Future predictions indicate that solar energy will be one of the most significant energy sources worldwide due to its abundance, cleanliness, affordability, accessibility, silent operation, small carbon footprint, and long, healthy life cycle (Tasneem et al., 2020). Solar energy is the most widely recognized forms of renewable energy, followed by geothermal, hydropower, and biomass (Karytsas & Theodoropoulou, 2014). Solar energy possesses considerable potential to satisfy the expanding global energy demands while concurrently reducing greenhouse gas emissions due to its cleanliness, abundance, reliability, sustainability, and predictability attributes (Rahut et al., 2018). The costs of renewable energy technologies specifically solar power has decreased significantly during the past twenty years compared to fossil fuel technologies (Timilsina, 2021). Thus, it is worthy to use solar energy in agricultural activities in Bangladesh considering the increasing negative impacts of fossil fuel.

In agriculture sector sustainable energy strategy advocates for using solar energy source, especially in rural areas of the globe where solar power is abundant(Chel & Kaushik, 2011). There is a growing need for agricultural reforms in the developing countries, as it is widely believed that implementing sustainable farming techniques can prevent the depletion of earth's natural resources (Afsharzade et al.;2016). In light of the significant emission of greenhouse gases associated with the agricultural sector, farmers must embrace sustainable and environmentally conscious practices, including alternative energy technology and organic cultivation (Aroonsrimorakot & Laiphrakpam, 2019). These sustainable agricultural practices would providesafeguard against a range of human illnesses and health implications, such as cancer, respiratory conditions, and other diseases linked to air and water pollution, as well as climate change (Schnepf, 2003). Using solar energy to enhance agricultural output and promote ecological protection is a very efficient strategy, and experts have been conducting thorough research on solar-powered irrigation for an extended period of time in the contexts of home and abroad (Yu et al., 2018;Islam & Hossain,2022).

In accordance withMir et al. (2021), the worldwide consumption of renewable energy amounted to 171 GW in 2018 representing a growth of 7.9 percent attributed to solar-wind energy. India possesses a renewable potential of approximately 900 GW, with wind (12%) and solar (83%) contributing the most followed by bioenergy (3%) and minor hydropower (2.2%) (Singh & Gautam, 2018).It is shown infigure 1

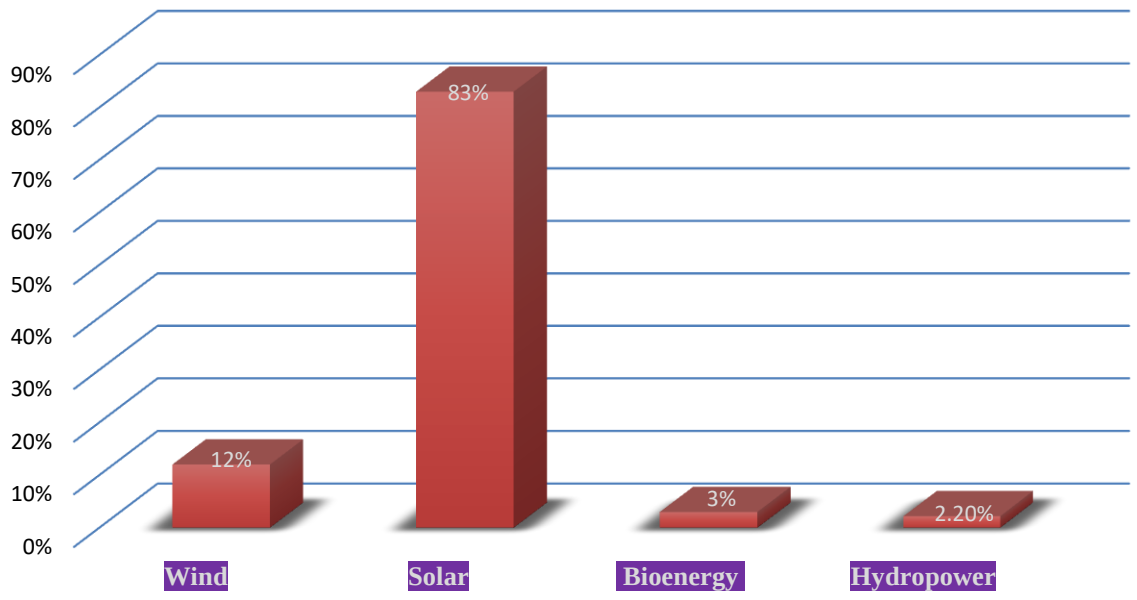

Figure 1. Status of renewable energy in India, 2018 **(**Mir et al.,2021)

In contrast, Bangladesh is going behind India as Bangladesh's energy equilibrium consists of 83,964 gigawatt hours (GWh) of nonrenewable and 1,175 GWh of renewable energy. The distribution of renewable energy sources in Bangladesh is as follows: 777 GWh from hydro and marine power, 389 GWh from solar power, 5 GWh from wind power, 4 GWh from bioenergy, and none from geothermal power (Koons, 2023, March 28).

Bangladesh is one of the lowest per capita energy consuming nations in the world. Furthermore, power outages have become a significant issue for Bangladesh and it harms the country's socioeconomic development. As a result, the country is looking for increasing its renewable energy sector to address the demand-supply gap, as energy is a crucial indicator of economic and social progress (Islam et al., 2014). Rural communities in Bangladesh are switching to renewable energy that might solve energy shortage (Islam et al., 2008). Power shortages and other energy industry issues make it hard to build the economy, and in the interface of fossil fuel-based energy use and its resultant environmental depletion, finding new energy sources is a priority in Bangladesh(Islam et al., 2014).Bangladesh has 967 Megawatt (MW) of renewable energy, which accounts 3.7% of its installed power production capacity. Bangladesh may save over $1.1 billion a year on fuel imports by switching from diesel-powered irrigation systems to solar ones and installing 2,000 MW solar panels (Zami, 2023).In2021, the government of Bangladesh uplifted this goal from 30% to 40%. As solar energy is renewable and eco-friendly its use can help reduce environmental damage, pollution, and fossil fuel use in Bangladesh. Thus, solar energy transition is the final measure that would allow us to lessen our dependency on fossil fuel progressively (Khalaf et al., 2015). To combat its energy crisis, Bangladesh has followed the footsteps of other countries by prioritizing renewable energy sources, particularly solar power (Marzia et al., 2018).Additionally, many government officials and scientists favor solar energy technology for its multiple societal benefits, one of which is that it provides cleaner energy (Kim et al., 2014). The development of solar energy to mitigate energy poverty, fuel crises, and electricity shortages in Yemen and other developing nations is an important headway that is heavily impacted by contextual, psychological, and individual aspects that determine public acceptance (Baharoon et al., 2016). The attitude and behavior of the consumers about renewable energy sources are critical for achieving energy goals and ensuring a sustainable future (Irfan et al., 2020). By prioritizing initiatives to increase household wealth, education, and awareness, policymakers can facilitate the adoption of solar energy in rural residences (Guta, 2018). Gender, age, educational attainment, environmentally conscious behavior, and engagement with engineering, technology, or environmental-related professions and study are crucial to accept renewable energy of the households (Karytsas & Theodoropoulou, 2014).

To achieve the provision of affordable and environment friendly energy, especially in the rural regions this research examined the participants' perspectives regarding the use of solar power and identified the influencing factors(Thompson et al., 2021). It is found that factors like family size and composition (including the number of adult males and children under 15 years), the household head's educational attainment, and the household's overall wealth impact the adoption decision of solar energy in residential settings (Rahut et al., 2018).Based on the above literature, it was not found the adaption of solar irrigation pumps in the north parts of Bangladesh. Thus, the objective of this study was to determine factors like education, experience, family size, income, training, peer relation, relative price (ratio of traditional price to solar price per decimal), and social capital, etc. that influenced farmers' decisions for the adoption of solar irrigation pumps in the study region of Bangladesh.

2. Research Methodology

2.1 Study area and data collection

The study is based on primary data collected directly from the farmers of Thakurgaon and Dinajpur districts situated in Northern Bangladesh. This region is considered as a very significant region for agriculture in Bangladesh. For this study a total of 206 farmers are randomly selected and interviewed using a structured questionnaire. Among the 206 respondents, 100 respondents are selected from Thakurgaon district and the rest 106 respondents are selected from Dinajpur district.

2.2 Empirical Model

In order to analysesthe determinants that influence farmers' decision to adopt solar irrigation pumps, a logistic regression model is used whether a farmer will accept the service or not. The model includes a total of eight explanatory variables to elucidate farmers' adoption of sustainable agricultural practice in terms of adopting this technology. The variables used in this study are chosen based on existing literature and objectives of the study.The regression model takes the form of equation (1).

$$\text{Ln}\left[\frac{P(Y)}{1-P(Y)}\right] = \beta_0+\beta_1X_1+\beta_2X_2+\ldots+u \quad (1)$$

Where, the dependent variable is the log of odd ratio of the probability of respondents' adaption of solar pump, and P(Y) stands for probability that the respondent is adopting of solar irrigation pump service and1-P(Y) is the probability that the respondent is not is adopting of solar irrigation pump service.Specification of the regression model asshown in equation (2).

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + u \quad (2)$$

Where,Y is a dummy variable assuming value 1 if the farmer adopts solar irrigationpump and zero otherwise, X_1stands for education of the household head, $X_2$for experience of the household head, X_3 for land size of the household head, $X_4$for peer relationship with other farmers, X_5 for income of the household head, X_6 for training received by household head, X_7 for relative price of irrigation using solar pumpand X_8 for social capital index for the household.$\beta_0 \ldots \beta_8$ are coefficients to be estimated and *u*isthe stochastic disturbance term.

2.3 Measurement of Dependent and Independent Variables

The unit of measurement for all variables is not similar since different variables are used in the model, as shown in Table 1. The dependent variable, the adoption of the solar irrigation pump, is measured as a binary variable in the model. "1" implies adoption, while a value of "0" indicates otherwise. The explanatory variables comprise continuous and dummy variables, each identified by its unit of measurement.

Table 1. Variables used in the regression model

Variables	Type	Measurement unit
Adaption of solar irrigation pump (Y)	Dummy	1=yes, and zerootherwise
Education of the farmer (X_1)	Continuous	Year
Farming experience of the farmer (EXP)	Continuous	Year
Land size of the farmer(LS)	Continuous	Bigha (1bigha=33 decimals)
Peer relation(PR)	Dummy	1=yes, and zero otherwise
Income (I)	Continous	Taka
Training (Tr)	Dummy	1=yes, and zerootherwise
Relative price (RP)	Continuous	Ratio of solar irrigation price to traditional irrigation price
Social capital (SC)	Continuous	Composite index

Education and experience are continuous variables that are measured over the years. Additionally, the land is measured in bighas, with one bigha equaling 33 decimals. Peer relation is binary, with "1" denoting the relationship to other farmers and "0" for otherwise and

income used in taka. The training dummy variable was coded as "1" for existence and "0" otherwise. Relative Price is the ratio of solar irrigation expenses to traditional irrigation prices. The social capital index was constructed by incorporating specific interactions, including the tendency to become a group member, social gathering, cooperative attitude towards society, and relationship with the sub-assistant agriculture officer. Five-point Likert scale data was employed to develop the social capital index.These types of variables were used in the earlier literature(Guta, 2014; Mathijs, 2000).

3. Regression Results

The logistic regression model shows a number of significant factors that affect the adoption of solar irrigation pumps for sustainable agriculture in the Northern regions of Bangladesh. This is presented in Table 2 where it is found that there issignificant positive feedback from level of education to adoption of solar irrigation pumps and the coefficient is significant at 1% level. It is normally expected that the farmers who havehigher levels of education, are more likely to adopt solar technology. Similarly, experience in farming had positive and significant effect on the adoption of solar irrigation pumps. Positive peer relationships are also recognized as an essential factor which indicated that social networks and interactions within the community have significant impact on the adoption of the new irrigation technology. The relative cost of irrigation using solar pumps is another factor that plays a significant impact in determining whether farmers are willing to adopt the SIP. Contrary to our expectation, the variables- income, training, and social capital have no significant effect on the decision to adopt solar irrigation pumps. In addition, size of the farm measured in total land cultivated did not appear as a factor in the adoption of SIP. This means that size of the farm is indifferent to the farmers in making their decision towards adoption of solar irrigation pumps.

Table 2: Logistic regression results

Model	Coefficient	Standard error	t- value	p-value
Constant	-0.074	0.119	-0.618	0.537
Education of the farmer	0.042***	0.007	5.828	0.001
Farming experience of the farmer	0.008***	0.002	4.258	0.001
Land size of the farmer	0.002	0.007	0.290	0.772
Peer relation	0.373***	0.061	6.141	0.001
Income	0.002	0.005	0.2853	0.383
Training	-0.064	0.058	-1.103	0.271
Relative price	0.126**	0.056	2.254	0.025
Social capital	-0.014	0.032	-0.429	0.668
Cox & SnellR-square = 0.605, No. of observation = 206				

R^2= 0.605; ***, **, and *indicate significant at 1%, 5% and 10%, respectively.

Source: Authors' estimation based on field survey data.

The model estimation is satisfactory as the indicated by the Cox and Snell R-square value of 0.605. This means that around 60% percent of the variations in the dependent variable, the logit, are explained by the explanatory variables used in the study.

4. Major Findings

In Northern Bangladesh, the factors that influence the adoption of solar irrigation pumps (SIPs) for sustainable agriculture are identified from the regression results.The feedbacks on SIP adoption from education and agricultural experience are found to be statistically significant, suggesting that farmers possessing greater expertise and knowledge are more inclined to adopt solar technology. This finding emphasizes the significance of human capital in facilitating technological advancements in the agricultural sector, which is consistent with the earlier findings of the study(Ainembabazia&Mugishab, 2014). Furthermore, it is worth noting that positive peer relationships remain a pivotal determinant in motivating the adoption of SIP. This underscores the importance of social networks and community engagements. Considering the relative price, adoption decisions are affected by how much SIPs cost compared to other options. This shows how much important cost-effectiveness is in the decision-making process.However, significant insights are also revealed by the regression analysis. Contrary to our expectation, the variables- social capital, training, and income did not influence the adoption decision of the farmers. On the other hand,the variable 'land size' does not have a substantial impact on adoption decision. This observation implies that the size of land holdings not exert a significant influence on farmers' adoption of solar services. In general, these results enhance the

farmers'comprehension of the complex elements that influence the adoption of technology in the agricultural sector and emphasize the necessity for focused interventions to encourage the extensive implementation of sustainable agricultural practice in the northern regions of Bangladesh.

5. Conclusion

Sustainable agriculture is important in Bangladesh, especially in the northern part, where agriculture is the main driving force of the economy. Solar irrigation pumps (SIPs) arean important tool in the ongoing development of agriculture. This study revealed the dynamics of rural technology acceptance by identifying numerous key parameters impacting farmers' SIP adoption. SIP adoption is strongly influenced by education and farming experience, underscoring the importance of knowledge and expertise in adopting new agricultural technologies. SIP use ishigher among farmers with higher education and experience, highlighting the relevance of human capital in agricultural technological innovation.Positive peer ties also influenced SIP adoption, highlighting the importance of social networks and community interactions in farmers' decisions.SIP adoption is not affected by land size, suggesting that farmers' decisions are not simply based on their activities.

This emphasizes the necessity for policies and activities that meet farmers' different needs and conditions, regardless of landholding size.Moreover,regional socioeconomic considerations and farming methods limit the study's applicability outside Northern Bangladesh. In addition, income impacts schooling, and SIP adoption which is ignored in the study.Notwithstanding, increasing SIPs in the Northern Bangladesh could improve agricultural sustainability and reduce the environmental impact of traditional irrigation systems. Policymakers, researchers, and development partners should come forward to help the country shifting a more resilient and environmentally friendly agriculture system by addressing adoption determinants.

Acknowledgement

The authors acknowledge the Institute of Environmental Science (IES), the University of Rajshahi (RU), the Directorate of Secondary and Higher Education (DSHE), and the Ministry of Education for this research work.

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