Plant Archives Vol. 25, No. 2, 2025 pp. 1371-1378 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.2.198

FACTORS INFLUENCING SOLAR ENERGY PUMPS ADOPTION IN RAJASTHAN'S SCHEDULED AREA: AN APPLICATION OF LOGIT MODEL

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(Date of Receiving-03-07-2025; Date of Acceptance-18-09-2025)

ABSTRACT

The scheduled area of Rajasthan relies heavily on groundwater for irrigation in agriculture due to insufficient rainfall and lack of surface water. The majority of irrigation systems in the scheduled area run on diesel or electricity, which increases the cost, energy demands and pollution in the environment. Utilizing the abundant sunlight and the widespread use of solar-powered irrigation systems is anticipated to be an appropriately recognizable experience for irrigation needs. Thus, using field survey data collected from 120 tribal farmers in Rajasthan's Udaipur district, this paper recognizes the factors determining the adoption of solar energy pumps. The logistic regression model was used for empirical analysis of the research to determine factors of solar energy water pump adoption. The findings showed that the size of farmer's land holdings, their annual income, their access to credit, their family size, their knowledge of the solar energy pumps (SEPs) subsidy, their level of education and their age had substantial influence on adoption decisions of solar energy pumps in the study area.

Key words : Solar energy pump, Adopter, Non-adopter, Logit model.

Introduction

Solar energy has the potential to transform agricultural sector by conserving precious water resources, reducing reliance on the grid, and even providing farmers with an additional revenue stream (The Indian Express, 2022). Solar energy may also serve to reduce the government's electricity and diesel subsidy bill, as well as farmer's reliance on unreliable power supply and expensive diesel. Thus, use of solar energy for agriculture purposes is a promising aspect with a capacity to significantly increase farmer's income by lowering irrigation costs and improving irrigation access (Upadhyay *et al*., 2024).

India is the world's third largest electricity consumer and third largest renerwable energy producer, with 40 per cent of energy capacity installed in 2022 (160 GW of 400 GW) coming from renewable sources (Upadhyay *et al*., 2023).

Rajasthan is a leader in the adoption of standalone solar pumps. Being inadequate and irregular rainfall, recurring droughts, and a scarcity of perennial water sources, the state has been innovative in integrating water conservation initiatives with solar pump projects. About 28.95 per cent of the state's gross value added in 2022-23 came from the agriculture sector, which also provides a significant portion of the state's rural population income (DES, Rajasthan, 2022-23).

Rajasthan government has implemented several supportive solar schemes, policies and programs to promote solar energy for various purposes, especially for irrigation. These includes Solar Pumping Scheme (2010), Rajasthan Solar Policy (2019) and Component A, B, and C of PM-KUSUM Scheme (Iqbal, 2020; Kalamkar and Sharma, 2020; Ranjan, 2020).

Solar-energised pumps spreading across scheduled area in Rajasthan can be a solution to the rising energy and climate concerns related to agriculture. The rate of adoption of solar- energy pumps is induced by various factors, including economic, environmental, and socio-economic factors, particularly rural tribal households in scheduled area of Rajasthan. Given this context, this research tried to identify the key factors which determine the farmer's adoption of solar-energy pumps in the study area.

Materials and Methods

Sampling plant

Government of India designated eight districts of south-eastern part of Rajasthan state as Schedule Area (Fig. 1) *viz*., Banswara, Chittorgarh, Dungarpur, Rajsamand, Pratapgarh, Pali, Sirohi and Udaipur which covered 5697 villages with a tribal population of more than 50 per cent (Government of India, 2018). The scheduled area has a population of 64.63 lakhs, with scheduled tribes accounting for 70.43 per cent of total population of Scheduled Area (Tribal Area Development, GOI, 2011).

The study was based solely on Primary data. For this, a multistage sampling method was employed to study solar energy water pumps in agriculture. At the first stage, the Udaipur district of Rajasthan was chosen because it had the second highest installation of solar water pumps under PM-KUSUM Component-B for fiscal year 2020-21 (Department of Agriculture, Government of Rajasthan, Jaipur). In the second stage, two tehsils from the Udaipur district were chosen. The district statistical handbook provided a list of solar water pumps installed during the fiscal year 2020-21 and the top two tehsils based on the highest number of installations of solar energy pumps namely, Jhadol and Kotra, were chosen (Fig. 1).

Two villages from each tehsil were chosen as having the highest number of solar water pump set adopter-farmers. "Ambasa" and "Amba" villages from Jhadol tehsil, and "Gaupeepla" and "Gura" villages from Kotra tehsil were chosen.

Simple random sampling technique was employed in the fourth stage to choose sample farmers from the selected villages. A detailed list of tribal farmers with solar water pump sets in the chosen village was compiled, along with the date of installation of the solar water pumps. Farmers who have used a solar water pump for at least three years are considered adopters. As adopters, 15 farmers from each village were chosen at random. Thus, a sample of total number of adopter farmers was 60.

To ensure a fair comparison, an equal number of farmers (60) without solar energy water pumps were chosen at random from the same villages with similar resource conditions as non-adopters. Farmers who adopted SEP were referred to as adopters, while those who did not adopt solar water pumps were referred to as non-adopters, for convenience.

Primary data were gathered from 120 farmers during the agriculture year 2022-23. Face-to-face interviews were conducted between February and April 2023 to collect the necessary data on various aspects of solar energy operated water pumps using a suitably semi-

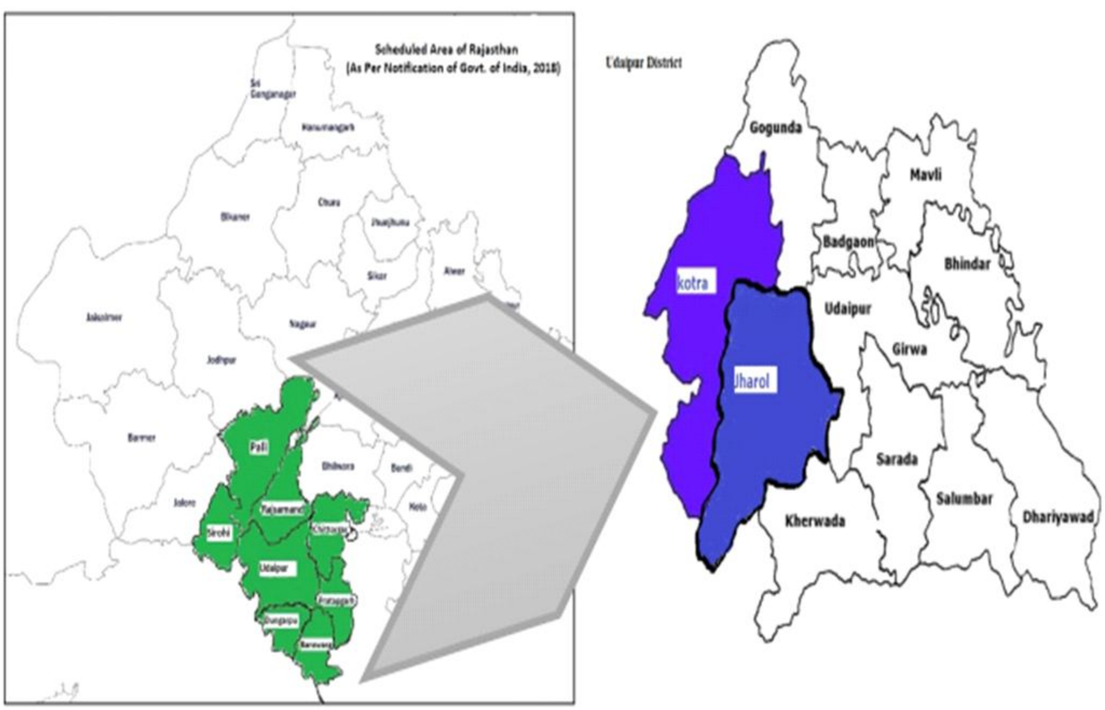

Fig. 1 : Location Map of scheduled Area and study area (Udaipur District) of Rajasthan State.

structured interview schedule. Before finalisation, the interview schedule was translated into the local language and pretested. During interviews, researchers enquired farmers about their adoption or non-adoption behaviour of solar pumps.

Analytical methods

Logistic Regression Model (Logit Model)

The logistic regression model (logit model) was used for empirical research to determine factors influencing solar energy pump adoption. After transforming the dependent variable into a logit variable, the model employs maximum likelihood estimation (Swider *et al*., 2008). When the dependent variable is dichotomous and the independent variables are of any type, logistic regression is appropriate. The independent variable predicts the likelihood of a specific event occurring, and the dependent variable is binary, which is the natural log of the odds (logit). We consider the following logistic regression model to estimate the factor that determines our study area farmer's adoption or non-adoption decision of solar energy pump:

$$Z = \ln\left(\frac{p}{1-p}\right) = a + \sum_{i=1}^{12} b_i x_i + \in_i \tag{1}$$

$$p = \frac{e^{a+bx_i}}{1+e^{a+bx_i}} \tag{2}$$

Where,

Z = binary outcome variable

p = probability of farmers adoption of solar energy pump

α = constant with x_i (independent variables) affecting the probability of solar energy pump adoption

b_i = estimated coefficient of explanatory variables

x_i = predictor variables

e = base of the natural logarithm

$\in_i$ = stand for the error term

i = 1, 2, 3, ..., n

$\ln\left(\frac{p}{1-p}\right)$ is the logarithm of odds of farmer's

Table 1 : Dependent and Explanatory Variables used in Binary Logistic Model.

Variables	**Types**	**Measurement unit**	**Description**
Dependent variable	Binary	Yes/No	1 = Adopter of solar energy water pumps; 0 = non-adopter of solar energy water pumps
Explanatory variables			
Household's income	Continuous	Indian rupees	Annual income of households from agriculture in rupees
Distance to market	Continuous	Kilometres	Distance of nearest market for solar pumps from village in kilometres
Farming experience	Continuous	Years	Households farming experience in years
Size of landholdings	Continuous	Hectares	Land possessed by household in hectares
Training access	Binary	Yes/No	**1** = Farmer access knowledge of solar water pump through any training programme;**0** = otherwise
Credit accessibility	Binary	Yes/No	**1** = Farmer have facility of credit to purchase solar water pump through any institutional sources;**0** = otherwise
Media access	Binary	Yes/No	**1** = Farmer have media access as sources of information of solar water pump; **0** = otherwise
Awareness about SEP's subsidy	Binary	Yes/No	**1** = Farmer have facility of credit to purchase solar water pump through any institutional sources; **0** = otherwise
Farmers contact with extension service providers	Binary	Monthly/bi-annually	**1** = Farmer monthly meet with extension service; **0** = otherwise
Education level	Binary	Literate/ illiterate	**1** = Literate (can read, write and sign the name); **0** = otherwise
Age	Continuous	Years	Household's head age in years

decision to adopt solar energy pump (Z = 1) versus not adopt (Z = 0).

A dummy variable is used to determine whether a household is a potential solar energy pump adopter or not. Z is a dichotomous dependent variable, with Z = 1 for solar energy pump adopters (farmers who used SEP) and Z = 0 for non-adopters (farmers who did not use SEP). The following empirical model is obtained in this study:

$$P_r Z = \frac{1}{1+e^{-(a+bx_i)}}$$

Measurement of key dependent and explanatory variables

The explanatory variables selected for this research were based on the literature already published on the adoption of solar energy pump technology *i.e.*, Sarkar and Ghosh (2017), Agrawal and Jain (2018), Jain and Shahidi (2018), Kumar *et al*. (2019), Sanap *et al.* (2020) and their description are given in Table 1.

Results and Discussion

Descriptive analysis of selected farmers on continuous variables

The outcomes of the descriptive analysis of adopters and non-adopters on continuous variables are summarised in Table 2. The significance of continuous variables on the adoption of SWP's was examined using student's t-test. Descriptive analysis findings suggested that SEP adopter's mean annual income (` 103500) was higher than non-adopters' (` 87833). The t-value showed that there is a sizeable mean difference between those who have adopted the solar energy pump and those who have not. This result was consistent with that of Zeru and Guta (2020).

Between adopters and non-adopters, there was a sizeable difference in the market's distance for buying and selling purposes (21.67 vs. 25.97 kilometres). The market area's distance revealed that the majority of non-adopters lived comparatively far from the market area, making it difficult for them to access market data on the various solar system manufacturers.

Adopters had a farming experience of 34.35 years, whereas non-adopters had a farming experience of 32.33 years. The t-value revealed that there was a significant difference in land holdings among adopters and non-adopters. As regards size of landholding, adopters had occupied more land (1.19 hectares) than non-adopters (0.81 hectare). This difference between adopters and non-adopters is statistically significant. Guta (2018), Zeru and Guta (2020) and Ahmed *et al*. (2022) made similar observations.

The average family size for adopters was 5.23 members, while it was 4.33 members for non-adopters. This indicates that households that used the solar energy pump had fewer children than non-adopter households. The t-test result showed that there was a significant mean difference in family size among adopters and non-adopters.

The average age of adopters was 51.38 years, while non-adopters were older (57.83 years). The age of households differed significantly among adopters and non-adopters. This indicates that adopters were comparatively younger than non-adopters. This finding is also correlated with Zeru and Guta (2020), Ahmed *et al*. (2022) and Aarakit *et al*. (2021). Guta (2018) on the other hand, noticed that household heads of SHS adopters are elder than non-adopters.

Descriptive analysis of sample farmers for discrete variables

Table 3 revealed the results of a descriptive analysis of solar water pump adopters and non-adopters based on discrete variables. For assessing the significance of discrete variables, the Chi-square test was performed. The study's findings revealed that 63.33 percent of sample adopters had received training on how to use SEP's in their agricultural operations, while only 33.33 percent of non-adopters had responded that they had.

The vast majority (75%) of adopters had access to credit. Most non-adopter farmers (68.33%) did not have access to credit. The chi square test revealed a statistically significant difference in credit-accessibility between adopters and non-adopters. Regarding media access such as radio, television and cell phone, the majority of adopters (61.67%) had access to media, whereas the non-adopters (73.33%) had not. No statistically significant link between household decisions to adopt SEPs and media access was found by the chi-square test.

Awareness about SEP subsidies was among the major elements promoting the acceptance of SEPs. The analysis found that 100 percent of adopter-farmers were aware of the SEP subsidy, while only a small percentage of non-adopters (13.33%) were aware of the SEP subsidy. Furthermore, there was a significant difference in adopter's and non-adopter's awareness of SEP's subsidy.

Only 30 per cent of non-adopters had monthly contact with extension agents, compared to about 60 per cent of

Table 2 : Descriptive Statistics for continuous variables.

Explanatory variables	Adopters	Non-adopters	Mean difference	Combined mean	t-value
Household's income	103500	87833	15666	95666	1.78*
Distance to market	21.67	25.97	-4.30	21.82	2.55***
Farming experience	34.35	32.33	2.02	33.34	0.99
Size of land holdings	1.19	0.81	0.38	1.00	4.70**
Family size	5.25	4.33	0.92	4.79	3.97**
Age	51.38	57.83	-6.45	54.61	3.52**

*Significant at 10% probability level, **Significant at 5% probability level, ***Significant at 1% probability level. Source: Authors' computation.

Table 3 : Descriptive Statistics for discrete variables.

Variables	Response	Adopters		Non-adopters		Chi^2 value
		No.	Percentage	No.	Percentage	
Training access	Yes	38	63.33	20	33.33	13.25
	No	22	36.67	40	66.67	
Credit accessibility	Yes	45	75.00	19	31.67	11.54***
	No	15	25.00	41	68.33	
Media access	Yes	37	61.67	16	26.67	9.54
	No	23	38.33	44	73.33	
Awareness about SEPs subsidy	Yes	60	100.00	8	13.33	8.62**
	No	0	0.00	52	86.67	
Frequency of contact with extension service	Monthly	36	60.00	18	30.00	2.89
	Bi-annually	24	40.00	42	70.00	
Education level	Literate	44	73.33	11	18.33	3.44**
	Illiterate	16	26.67	49	81.67	

**Significant at 5% probability level, ***Significant at 1% probability level. Source: Authors' computation.

adopter-farmers who did so to learn about various types of services.

Only 18.33% of non-adopters were found to be literate, compared to about 73.33 percent of adopters. The study found that household heads who received higher education were more likely to be adopters than non-adopters. The chi-square test showed statistical relation among household head's educational attainment and their choice to adopt SEP. This conclusion is consistent with studies from Guta (2018), Zeru and Guta (2020) and Aarakit *et al*. (2021).

Factors influencing farmer's decision to adopt solar water pump

Table 4 indicates the factors which influenced the farmer's choice to accept solar energy pump along with the outcomes of binary logistic regression. Out of the 12 explanatory variables involved in the model, 5 variables have a statistically significant influence on farmer's choice to adopt SEP. McFadden's R-square or pseudo R^2 was 0.71, indicating that the model's covariates explained 71 per cent of total variation in the probabilities of household's adopting solar water pump.

Household's income

The study found that farmer's income has a positive and statistically significant influence on solar energy systems. The binary logistic regression model's odd ratio indicated that as household income increased by one rupee, the likelihood of adopting a solar energy pump increased by a factor of 0.99. This finding is consistent with Smith (2014), De Groote *et al*. (2016) and Aarakit *et al*. (2021).

Table 4 : Results of the Logistic regression Model employed for Solar Energy pumps adoption.

Particulars	Coefficients	Standard Error (SE)	Z Value	Odds ratio	P values
Household's income	0.0001*	0.0000	2.04	0.99	0.0041
Distance to market	-0.006	0.0324	-1.80	0.94	0.0714
Farming experience	0.019	0.0272	0.68	1.02	0.4935
Size of land holdings	2.772**	0.8564	3.24	15.99	0.0012
Training access	0.428	0.6041	0.71	1.53	0.4790
Credit accessibility	2.059***	0.6154	3.35	7.84	0.0008
Media access	0.908	0.6184	1.47	2.48	0.1420
Awareness about SEP subsidy	0.110***	0.0120	9.17	0.31	0.0011
Farmers contact with extension agents	-0.209	0.5650	-0.37	0.81	0.7110
Education level	0.171***	0.0145	11.75	1.18	0.0321
Family size	0.466*	0.2346	1.99	1.59	0.0467
Age	0.082**	0.0339	-2.41	0.92	0.0158
McFadden's R^2/ Pseudo R^2	0.712				
Chi square	124.36				

*Significant at 10% probability level, **Significant at 5% probability level, ***Significant at 1% probability level. Source: Authors' computation.

Size of land holdings of farmers

Size of land holdings was significant at 5% L.O.S., with a positive sign of the coefficient (2.77) indicating a positive relationship with the likelihood of adopting a solar water pump. This result is in line with Choudhary *et al.* (2022). The odd ratio is 15.99 (more than one), implying that increasing the size of land holdings by one unit, increases the likelihood of using a solar water pump by 15.99 times.

Credit accessibility

The farmer's decision to employ a solar water pump was influenced positively by the coefficient of credit accessibility to farmers (2.06). Furthermore, the estimated odd ratio (7.84) indicated that as farmer's access to credit increased, the likelihood of adopting solar water pumps increased 7.84 times. Gwavuya (2012), Ali *et al*. (2016), Mengistu *et al*. (2016), Kizilcec *et al*. (2021) and Wassie *et al*. (2021) support our findings.

Awareness about SEP's subsidy

The knowledge of SEP's subsidy was important and positively impacted the decision of utilizing a solar water pump. From the model result, the odd ratio of 0.31 in favour of adopting solar water pump increased by a factor of 0.31 for a unit increase in its counterparts. This suggests that farmers who were aware of the government incentives for SEPs were far more likely to adopt them than farmers who were partially or totally unaware of their advantages. This result is consistent with those of Naomi (2014), Zeru and Guta (2020), Ahmed *et al*. (2022), Sunny *et al*. (2022) and Sunny *et al*. (2023).

Education level of farmers

Farmer's decisions to adopt SEP were positively influenced by the coefficient of educational attainment (0.17). The model statistics odd ratio showed that the farmer's decision to adopt SEP increased by 1.18 times as their level of education rose. The study's findings showed that farmers, who were educated and literate were more eager to adopt solar water pumps than farmers who were illiterate. Better access to education increases a household's ability to learn about, comprehend, and be aware of new renewable energy technologies.

Family size

Significantly and positively influence farmer's decision to adopt solar energy pumps. It means that for every one-unit increase in family size, the likelihood of adopting solar energy technology rises by 2.16 times. Other things being the same, the odds ratio of family size indicates that for every one-unit increase in family size, the likelihood of adopting solar energy technology rises by 1.59 times. This finding is supported by Rahut *et al*. (2017), Guta (2018), Ahmed *et al*. (2022), but contradicted by Anteneh (2020).

Age of farmers

The estimated model coefficient (-0.08) showed that the farmer's decision to adopt SEP was negatively impacted by his or her age. Furthermore, the model's estimated odd ratio (0.92) implied that for every unit increase in the farmer's age, the decision to adopt a solar water pump decreased by 0.92 times. This clearly show that older farmers were more hesitant to adopt solar water pumps than younger ones.

Conclusion

Both standalone solar technology and solar energy pump technology possess the potential to close the widespread energy accessibility gap in the scheduled areas. Standalone solar technology additionally provides an instant, practical alternative to household-level electricity access. For a scheduled area of Rajasthan like Udaipur district, where electric network expansion is mostly limited to the urban area, the vast majority of rural residents have low electric grid connection. However, there are several factors which possibly affect the farmer's adoption of solar energy pump. Thus, this study aimed to analyse factors that determine farmer's adoption of solar energy pump.

The findings of the study from the binary regression analysis indicated that seven independent variables were significant in explaining the factors affecting rural household's adoption of solar energy pump. These variables were size of household's income, land holdings of farmers, credit accessibility, awareness about SEP's subsidy, education level of farmers, family size and age of the farmers which had significant influences. Based on the finding, the study recommends that the government should raise farmer's awareness through increased access of credit, education, subsidy on solar energy and especially improved credit services to rural households to increase the adoption of solar energy pump.

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