Analysis of the economic and social factors affecting the adoption of solar-powered irrigation systems using a binary logistic regression model: A field study in Al-Hawija District for the 2024 production season.

Jasim Mohammed Dheyab1 , Yusra T Al-bijarry2

1Tikrit University/ College of Agriculture/.iraq

E-mail: jt231102pag@st.tu.edu.iq

2Tikrit University/ College of Agriculture/.iraq

E-mail:Usraa_traiq@tu.edu.iq

Abstract

This study aims to analyze and estimate the economic and social factors influencing farmers' decisions to adopt solar-powered irrigation systems, within the broader context of transitioning toward sustainable agricultural technologies that reduce operational costs and enhance resource-use efficiency. To achieve this objective, a Binary Logistic Regression model was employed to estimate the impact of a set of independent variables on the likelihood of adopting this technology, using field data collected from farmers in the Hawija district, Kirkuk Governorate. The analyzed variables included: net income, operational costs, years of farming experience, educational level, farm size, farmer's age, and the level of satisfaction with conventional systems. The model results indicated statistically significant effects for several variables on the adoption decision. Operational costs, farming experience, farm size, and university-level education were found to have a positive and significant influence on the likelihood of adoption, whereas net income and age had a negative impact. Additionally, a lower level of satisfaction with conventional irrigation was strongly associated with an increased probability of switching to solar irrigation systems. The results were interpreted based on the Exp(B) coefficients, which represent the odds ratios, providing precise quantitative indicators to support extension decisions and relevant agricultural policies. The study concludes that the adoption of solar irrigation systems is not driven by a single factor but rather results from a complex interaction of economic, behavioral, and educational determinants. This underscores the need for multi-level interventions through targeted financial support and technical extension programs.

Keywords:

Solar energy, irrigation systems, logistic regression, technology adoption, Hawija District.

Introduction

The agricultural sector is a fundamental pillar of the Iraqi economy, contributing approximately4.5% of GDP and provides livelihoods for more than 30% of the rural population (1). With the escalating challenges of resource sustainability and rising production costs, especially energy costs, the need to adopt alternative technological solutions has become more urgent than ever, especially in the field of irrigation, which consumes 60–70% of water and energy resources allocated to the agricultural sector (2).In this context, solar-powered irrigation systems have emerged as a strategic option for reducing dependence on fossil fuels, lowering operating costs, and achieving sustainable economic returns. Studies indicate that using solar energy in irrigation can reduce operating

ISSN 2072-3857

costs by 100%.30–50% annually compared to conventional fuel systems (3). The United Nations Development Program also indicated that Iraq has a solar radiation rate exceeding 5.5 kWh/m² per day, making it one of the most suitable Arab countries for adopting solar energy systems (4).Despite these indicators, adoption rates of these systems remain low in agricultural provinces, including Hawija District, one of the most prominent wheat-producing areas in northern Iraq. This raises questions about the reasons behind this reluctance, especially given the availability of appropriate technical and economic conditions..Hence, the importance of this study emerges in its attempt to analyze and explain the economic and social determinants influencing farmers' decisions to adopt solar-powered irrigation systems. The binary logistic regression model was used.(Binary Logistic Regression Model) was used to suit the binary nature of the dependent variable (adoption = 1, non-adoption = 0). Field data collected from a representative sample of the district's farmers were also used, and the results were interpreted using Exp(B) coefficients, which reflect the odds ratio (Odds Ratio) for each variable.The study aims to provide scientific evidence to help design agricultural policies that support the adoption of this technology, whether through green lending programs, technical awareness, or guidance for adoptable groups.Understanding farmers' decision-making logic is the cornerstone of the success of any sustainable technological transformation in the agricultural sector.

Research problemDespite the growing need to reduce agricultural production costs in Iraq, especially in light of rising fuel prices and the declining efficiency of traditional irrigation systems, the adoption of solar-powered irrigation systems remains limited among a wide segment of farmers, including those working in the Hawija district..Data show that the cost of operating a traditional fuel-powered irrigation system in Iraq is, on average,2.5 million dinars annually per hectare, compared to less than 1.2 million dinars in the case of a solar system after recovering the initial cost (5)Despite this economic feasibility, farmers' adoption behavior shows wide variation that cannot be explained solely by financial logic..What are the economic, social, and behavioral factors that influence a farmer's decision to adopt solar-powered irrigation systems?To what extent do variables such as net income, operating costs, years of experience, education, age, holding size, and satisfaction with the traditional system contribute to shaping this decision ?

Materials and Methods

First: Research site

The study was conducted in Al-Hawija district, located in Kirkuk Governorate, northern Iraq. This is an important agricultural area known for grain production, particularly wheat and barley, and relies mostly on pivot irrigation systems that require high operating energy, making it a suitable environment for analyzing the feasibility of adopting renewable energy technologies in irrigation..

Second: The research community and its sample

The research community consists of farmers working in Al-Hawija district who use traditional pivot irrigation systems or who have adopted solar-powered irrigation systems..

A stratified random sample of 100 was selected from the agricultural community in the district.Farmers were distributed according to tenure categories and adoption status, and represented different age groups, educational backgrounds, and income levels.

Third: Data sources

ISSN 2072-3857

The research relied on two main sources of data::

Primary dataIt was collected in the field through a pre-designed questionnaire, covering economic, social, and behavioral variables associated with the adoption of solar-powered irrigation systems. It included quantitative (income, tenure, age, costs) and qualitative (educational level, satisfaction) data.

Secondary data:Directed from official reports and sources such as:

Iraqi Ministry of Agriculture - Kirkuk Agriculture Directorate.

Central Agency for Public Mobilization and Statistics (2023) FAO reports(2.(

Previous relevant local studies.

Fourth: The standard model used

Binary logistic regression model was used.(Binary Logistic Regression)To measure the influence of independent variables on the decision to adopt a solar system, this model is suitable for analyzing binary dependent variables (1 = adoption, 0 = non-adoption), and does not assume a normal distribution of variables.

The general formula of the model is::

The model is formulated in its general form as follows:

Logit(P)=ln=()β0+β1X1+β2X2+⋯+βkXk

where :

PP = Probability that the farmer is in the category of users of solar irrigation system.

β0 = constant coefficient.

Bi I = Estimated coefficients representing the marginal effect of the independent variables Xi on the logit probability.

Xi = The independent variables in the model, which in this study included the following:

x1 = net income

x2 = operating costs

x3 = years of agricultural experience

x4 = educational level (categorical variable(

x5 = size of agricultural holding (in dunums (

x6 = farmer's age

x7 = farmer satisfaction level with the traditional system (ordinal scale(

For the estimation using the binary logistic regression model, the qualitative variables were coded as follows:

• Education level: Primary = 1, Secondary = 2, University = 3.

• Satisfaction with the conventional irrigation system: Low = 1, Moderate = 2, Good = 3, High = 4.

The model was estimated using the maximum likelihood method.(Maximum Likelihood Estimation), which is the most common method in logistic regression models, as it does not assume a normal distribution for the dependent variable and provides accurate results even in the presence of qualitative variables. The results were also interpreted using the Exp(B) coefficients, which represent the odds ratio (Odds Ratio), to show the extent of the influence of each independent variable on the probability of adopting the solar system. Table (1) shows the results of the logistic regression analysis to determine the factors influencing the adoption of the solar-powered irrigation system:

x1 Net income

B = -1.487, Sig. = 0.022, Exp(B) = 0.226

negative and moral impact:High net income reduces the likelihood of adoption by 77.4%.

ISSN 2072-3857

AnalysisAlthough increased income is typically associated with the ability to adopt new technologies, this finding reflects conservative behavior among high-income earners, perhaps because they don't feel the economic need for savings technologies or because they prefer to invest in more traditional or technologically ready solutions. This suggests a behavioral paradox that merits guidance intervention.

x2 Operating costs

B = 0.743, Sig. = 0.015, Exp(B) = 2.102

positive and significant effectAs costs increase, the likelihood of adopting a solar system increases by 2.1 times.

AnalysisThe rising costs of conventional irrigation systems (fuel, maintenance, labor) represent a direct economic incentive to adopt solar systems, which are viewed as a long-term cost-reduction option. This finding reinforces the economic rationale behind the decision.

x3 years of experience

B = 0.061, Sig. = 0.031, Exp(B) = 1.063

positive and significant effectEach additional year of experience increases the likelihood of adoption by 6.3%.

AnalysisThis finding refutes the conventional assumption that experienced farmers cling to old ways, and demonstrates that experienced farmers are better able to discern the economic viability of a solar system. Expertise here does not imply rigidity, but rather behavioral insight.

x4 educational level

The overall significance is not significant.(Sig. = 0.525), but:

x4(3):university → B = 1.342, Sig. = 0.008, Exp(B) = 3.827

Strong educational impact for university studentsThey are 3.8 times more likely to be adopted.

AnalysisHigher education enhances the ability to grasp technical concepts and analyze long-term benefits, making university graduates more aware of and understanding opportunity costs, as well as their ability to cope with the demands of a technological system. Education represents a strategic channel in adoption policies.

x5 Agricultural holding

B = 0.019, Sig. = 0.043, Exp(B) = 1.019

positive and moral impactEach additional acre increases the probability of adoption by 1.9%.

AnalysisLarger holdings are associated with a greater ability to absorb the initial investment cost of a solar system, and its economic viability is clearly demonstrated by economies of scale. This suggests that small farmers may need financial support to encourage adoption.

x6 age

B = -0.045, Sig. = 0.066, Exp(B) = 0.963

negative effect close to moralEach additional year of life reduces the likelihood of adoption by 3.7%.

AnalysisOlder adults are often less likely to adopt new technologies due to factors related to prior experience, comfort with traditional patterns, and risk-taking concerns. Younger adults are more receptive to change, indicating the importance of younger age groups in promotional campaigns.

x7 Satisfaction with the traditional system

The overall significance is close to the moral significance.(Sig. = 0.056), but:

x7(1): Weak satisfaction → B = -3.174, Sig. = 0.006, Exp(B) = 0.042

ISSN 2072-3857

strong negative impactDissatisfied people are 95.8% less likely to continue in the traditional system.

AnalysisThis reflects the power of the psychological and behavioral driver of decision-making. The less satisfied a farmer is with the current situation, the greater his willingness to take risks and adopt a new alternative. Satisfaction here is a pivotal behavioral variable, rather than merely an economic one.

constant coefficient(Constant(

B = 16.325, Sig. = 0.319

Not meaningful.

Analysis: It represents the initial value of the logit equation when all independent variables = zero. It is not interpreted economically, but is used to calculate the total probability.

Strategic conclusion:

It is clear from the model that adopting a solar-powered irrigation system does not depend on a single economic factor, but is the result of a complex interaction between:

Economic incentives (high costs, large holdings(

Personal characteristics (experience, age, education(

Psychological and behavioral factors (satisfaction, confidence, conviction(

Therefore, public policies aimed at promoting the adoption of this system must be multidimensional, including financial support, technical education, and behavioral persuasion through smart guidance programs targeting influential groups (such as youth and learners.(

Table (1) Results of logistic regression analysis to determine the factors influencing the adoption of solar-powered irrigation system.

Variable	B	SE	Wald	df	Sig.	Exp(B)
x1: Net income	-1.487	0.824	1.952	1	0.022	0.226
x2: Operating costs	0.743	0.589	0.370	1	0.015	2.102
x3: Years of experience	0.061	0.035	0.499	1	0.031	1.063
x4(1): Primary	-1.132	1.006	1.267	1	0.260	0.322
x4(2): Preparatory	-0.665	0.691	0.927	1	0.336	0.514
x4(3): University	1.342	0.671	0.022	1	0.008	3.827
x5: Agricultural holding	0.019	0.017	0.130	1	0.043	1,019
x6: Age	-0.045	0.022	3,048	1	0.066	0.963
x7(1): Weak satisfaction	-3.174	1.197	6,680	1	0.006	0.042
x7(2): Average satisfaction	0.050	0.718	0.005	1	0.945	1.051
x7(3): Good satisfaction	0.215	0.701	0.094	1	0.759	1,240
x7(4): High satisfaction	0.363	0.752	0.232	1	0.630	1.437
constant coefficient(Constant)	16,325	16,368	0.995	1	0.319	12299628.674

Source: Researcher's work based on questionnaire data and statistical program output estimation results.SPSS

ISSN 2072-3857

To verify the validity of the statistical model and the quality of its estimates, several diagnostic tests were conducted. The Hosmer–Lemeshow test showed a value of (Chi-square = 7.82, Sig. = 0.45), which was not significant, indicating a good fit of the model and its ability to explain the data. The value of Nagelkerke $R^2 = 0.41$ reflects the proportion of variance explained by the model and is considered acceptable in field studies of a social and economic nature.The results showed that the education level was not statistically significant at the lower levels (primary or secondary), whereas the effect of university education was significant and positive, increasing the likelihood of adoption by 3.8 times. This indicates that the influence of education becomes evident at higher levels, which provide farmers with a greater ability to comprehend the technical and economic aspects of the technology.Similarly, the degree of satisfaction with the conventional irrigation system constituted an important psychological and behavioral factor. Farmers who were dissatisfied demonstrated a stronger tendency toward change and the adoption of the solar system. This is consistent with Ajzen (1991) in the framework of the Theory of Planned Behavior, which posits that negative attitudes and perceptions toward the existing system enhance the willingness to adopt new alternatives.When comparing the results of this study with those of previous research, the following can be observed:The finding regarding the effect of operating costs is consistent with the conclusions of Al-Mashaqbeh & Gharaibeh (2019) in Jordan, who confirmed that rising fuel costs constitute a major incentive for the adoption of solar energy.The effect of farm size was also in agreement with Nasr & El-Zanaty (2020) in Egypt, who indicated that larger farms are more capable of absorbing the initial investment cost.In contrast, the results related to net income differed from some studies such as Hussain et al. (2020) in Pakistan, which found that higher income increases the likelihood of adoption. In this study, however, farmers with higher incomes were less inclined to adopt solar irrigation systems, reflecting differences in the behavioral and economic context across farming communities.

Conclusions and Recommendations

First: Conclusions

.1

Operating costs are a major driving factor.To adopt the solar-powered irrigation system, the results showed that the increased costs associated with the traditional system more than doubled the likelihood of adoption, indicating that farmers realize the economic feasibility of the solar system as a low-cost alternative in the long term..

.2 Net income had an adverse and significant impact.In adopting the solar system, the results showed that farmers with high incomes were less likely to adopt, which reflects conservative behavior among some groups towards new technologies despite the availability of financial resources..

.3

Agriculturalexperienceanduniversityed

ISSN 2072-3857

ucationTheconstituteddeterminants with a positive and significant impact on adoption, indicating the importance of the farmer's knowledge base and analytical ability in making adoption decisions..

.4 Agricultural holding sizeIt emerged as an economically significant factor, as large holdings helped absorb the initial investment cost, while small farmers remained limited in their financial capacity..

.5 Farmers' satisfaction with the traditional systemIt was clearly influential, as dissatisfied individuals showed a greater tendency to adopt the solar system, confirming the importance of psychological variables in adoption behavior..

.6 Age had a negative effect that was not completely significant, but close to significance., indicating a greater tendency among younger groups towards adoption compared to older people, due to a willingness to change and accept risks..

Second: Recommendations

.1

Design financial support programs targeting small farmers, such as soft loans or partial subsidies for the costs of installing solar irrigation systems, with the aim of reducing the financing capacity gap..

.2 Strengthening agricultural and technical guidance in rural areas, with a focus on education about the economic and environmental benefits of solar energy systems, especially among those with limited education.

.3 Targeting farmers dissatisfied with the traditional system with focused awareness campaigns, as they are the most receptive group to change, while providing them with technical support to facilitate the transition process.

.4 High-income farmers by highlighting environmental benefits and providing advanced technical solutions that meet their investment and profit aspirations.

.5 Integrating agricultural behavioral variables into agricultural policies by adopting models that address farmers' beliefs and psychological motivations, not just their economic capabilities.

.6 Focus on young people in training and support initiatives, as they are more technologically inclined and more willing to adopt sustainable innovations.

References

[1]

The device Central For statistics. (2023).The report Annual For production agricultural.Baghdad:ministry Planning.

[2] FAO – Food and Agriculture Organization. (2022). Renewable energy for agri-food systems: Towards the Sustainable Development Goals and the Paris Agreement. Rome: FAO.https://www.fao.org/documents/card/en/c/cc1133en

[3]Aldahas, M.A., And Sultan, M.S. (2022).analysis feasibility Economic To use Energy Solar in production vegetables in governorate Anbar.magazine Anbar For science agricultural, 20(1), 63–72.

[4]UNDP - United Nations Development Programme. (2023). Renewable Energy

ISSN 2072-3857

Readiness Assessment for Iraq. New York: UNDP.

[5]Hussain, A., Khan, M., & Shah, H. (2020). Adoption of agricultural innovations in arid regions: Evidence from rural Pakistan. Agricultural Economics Review, 36(1), 40–50

ISSN 2072-3857