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Adoption of Solar Pumping Systems by Vegetable Farmers in Niayes Agro-Ecological Zone of Senegal: Adoption as a Sequential Process

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Abstract

This article examines the determinants of the adoption of solar pumping systems (PV) by vegetable farmers in the Niayes area of Senegal. To measure the determinants, we used a sequential logit model to translate the adoption process from becoming aware of solar pumping systems to testing them, *i.e.* using them at least once, and then continuing to use them over time. The results show that the main variables affecting awareness of the use of solar pumping systems (PV) are age, marital status, experience, access to credit, the farmer's knowledge of climate change, the farmer's origin in the Thiès region and length of time in the Niayes area. The first use of PVs is influenced by factors such as the size of the plot, the distance of the plot from the main road or from the market. Finally, the decision to adopt or continue use is influenced by gender, experience, household size and access to credit. Surprisingly, access to credit does not affect the first use of solar pumping systems, but plays a key role in their continued use.

Keywords

Solar Pumping Systems, Adoption, Vegetable Cultivation, Niayes (Senegal)

1. Introduction

The major challenge facing the World today is to pursue economic, social and ecological objectives at the same time [1]. Combining the pursuit of these three imperatives refers to the concept of sustainable development, which is often confused with the concept of green growth. However, green growth can only guarantee sustainable development if it does not lead to environmental degradation [2]. Green growth, which gained renewed interest after the 2008 financial crisis [3], is based in particular on the Keynesian and Schumpeterian approaches. According to the Keynesian approach, after a period of recession, investment in the promotion of renewable energies is likely to stimulate aggregate demand, which in turn stimulates growth. In relation to Schumpeter's idea, another growth lever is the use of low-carbon innovations in economic activities [4]. Following these approaches, the conclusion is that growth can be driven by the greening of economic activities. In the context of climate change, the Paris Agreement recommends the use of clean, sustainable energies to replace fossil fuels, whose negative impact on the environment and climate has been widely established [5] [6]. These alternative energies make it possible to maintain the central role that the energy factor plays in the economic development process, while reducing greenhouse gas emissions [7].

In line with Goal 2 of the Sustainable Development Goals (SDGs), to ensure food security for all and achieve zero hunger, sub-Saharan agriculture faces the challenge of being more productive while adapting to the context of climate change [8]. To meet this challenge, the promotion of intelligent agriculture based on food security, mitigation and adaptation to the effects of climate change will be one of the appropriate responses [9].

Globally, food insecurity affects nearly 2 billion people and hunger affects over 820 million; impacting their health due to the relationship between food and nutrition [10]. In sub-Saharan Africa, food insecurity and hunger are set to worsen in the coming years, as the region's population could rise from 860 million in 2010 to between 1.7 and 2.2 billion by 2050 [11] [12]. This population explosion will not only increase demand for arable land for food production, but also accelerate the disappearance of natural forests, which are carbon reservoirs [13]. Subsistence farming accounts for more than 20% of the region's GDP on average, and is largely dominated by family farms, which support 60% of the population [14]-[16]. These indicators support the findings of the Gollin et al study, which indicate that agriculture is more important in terms of occupation of the working population than in terms of contribution to value added in almost every country in the World, especially those in the developing world [17]. In Senegal, poor households are more vulnerable to the effects of climate change, and 75% of these households live in rural areas. What's more, poverty is highest among households headed by people working in agriculture. This sector feeds a large part of the population and employs more than half of all households [18]. Based on these observations, most policy and strategy documents recommend boosting the productivity of small family farms to combat food insecurity and poverty [19].

To improve agricultural productivity, conventional strategies consisted mainly, in regions that had experienced major agricultural revolutions, of the combined or uncombined use of improved varieties and chemical fertilizers. In Sub-Saharan Africa, these strategies were strongly recommended, even though the region did not benefit enough from the various revolutions in the agricultural sector [20]-

[22]. Also, instead of combining agricultural technologies, farmers may use them sequentially, starting with the least risky [23]. Whatever the strategy, the adoption of these agricultural technologies results in improved household welfare [24] [25], high self-consumption [26], and reduced poverty [27]. Agricultural intensification through the sole use of improved varieties and chemical fertilizers has not, however, achieved the desired results due to soil degradation [28]. Thus, sustainable land management that can improve soil fertility and prevent erosion and land deterioration is taken as an additional technology. As part of sustainable land management, climate-smart agricultural practices such as conservation agriculture (CA) and agroforestry have a considerable impact on yields and reduce the risk of low yields, even during rainfall breaks [29]-[35]. In a context of climate change, these sustainable agricultural practices are increasingly popularized and promoted due to their carbon sequestration potential.

The aforementioned agricultural technologies are geared more towards strategies for adapting to the effects of climate change, even if sustainable land management is one of the techniques for carbon sequestration. As for measures to reduce greenhouse gas emissions, they will be implemented through the use, for example, of renewable energies in productive spheres. To combat food insecurity, recently induced in part by the Covid 19 pandemic and currently by the Russian-Ukrainian crisis, and to reduce the negative impacts of agricultural activities on the climate, the use of climate-smart innovations in irrigation is deemed necessary [36]. These technologies are increasingly being promoted as they have the potential to transform agricultural systems and increase household resilience and well-being while reducing greenhouse gas emissions [37]. In general, access to energy is clearly established as a driver of agricultural development [38]. As for the promotion of clean energy in irrigation, it is in line with the logic of sustainable development, as this type of energy is cost-effective and ensures a sustainable energy supply that can boost agricultural production while protecting the environment [39]. GHG emissions from agriculture, particularly irrigated agriculture, could be reduced by replacing fossil fuels with renewable energies.

The climatic dimension, captured either by temperature [40] or by rainfall or by an index combining the two parameters *i.e.* the Standardized Precipitation and Evapotranspiration Index [41], is increasingly being taken as a determinant of agricultural growth [42]. This is because climate change has become a risk for agricultural production, especially that dependent on rainfall. The factors acting on supply can be explained by the adoption of new technologies, notably solar pumping systems. In relation to these technologies, some studies focus on their diffusion process [43] while others on the factors explaining their adoption [44] [45]. In summary, Boudet's 2019 study classifies the factors influencing adoption into four areas, namely factors relating to the technology, those relating to its adoption process, adopter characteristics and the environment or location in which potential adopters live. Following Boudet 2019, the adoption of a technology depends not only on its attributes but also on the facilities put in place to access the technology. The perceived importance of the technology, in our case the solar pumping system, is an important factor in most behavioral theories [46]. With regard to access to new technologies, authors [47] [48] assert that the implementation of policies or strategies making the technology attractive and profitable through, for example, the issue of quality certifications and the granting of tax benefits to local companies and subsidies to farmers could facilitate its adoption. Financing mechanisms, in particular the granting of credit to farmers, are also conducive to the adoption of solar technologies. In this sense, [49] find that financial aspects notably improved household income affect technology adoption [50]. In fact, difficult access to agricultural technologies, limited information on their use and low financial resources limit their adoption by small-scale producers, especially in sub-Saharan countries [51]. Beyond the problems of agricultural input distribution channels and producers' access to information, according to Suri 2011, non-adoption translates into a difference in yields obtained through the use of these technologies. Also, the profitability of the technology determines the adoption of agricultural technologies [52].

In relation to the characteristics of potential adopters, the conventional approach was to focus on the producer's income as the main explanatory factor for the adoption of solar energy, which often requires a large initial investment [53]-[57]. However, income has been found in some studies to be a non-determinant of adoption [58]-[60].

In their critical conclusions, [61] argue that the approach of considering income as the main predictor of solar or clean technology adoption decisions, deserves to be reviewed. Studies have therefore focused on other factors in addition to income, to highlight the determinants of solar technology adoption. These determinants are the socio-economic and institutional characteristics of producers. [62] consider adoption as binary, *i.e.* the household chooses clean energy or not for its supply, and find that the fact that the head of household is male reinforces this adoption. According to the authors [63]-[66] younger people adopt clean energy technology more than older people. It has also been found that more educated people adopt solar energy technology more [67]. In addition, Lee's (2005) study shows that household size positively affects the adoption of new technologies. Technology adoption also requires access to the credit market [68] [69]. Access to subsidies is also found to influence the adoption of new technologies [70].

The distinctive feature of the above studies is that they treated adoption as a binary choice. None of these studies took adoption as a sequential process. Lindner et al (1982) conceptualized adoption as a three-stage process: knowledge, testing and adoption (continued use). However, few authors have empirically studied adoption according to this approach [71] [72]. To our knowledge, in Senegal, there are no studies using adoption as a sequential three-stage process (Awareness, Testing and Adoption) concerning the adoption of solar technologies in agricultural production.

Given that Senegal's agricultural system is vulnerable to climate change, it is not only necessary to focus on water management for its development and to offset the increased occurrence of rainfall breaks noted in recent years, but also to integrate clean, low-cost energy solutions, especially in vegetable cultivation and rice-growing areas.

The Niayes area is the traditional granary for vegetable cultivation, although in the river valley these crops are becoming increasingly important. However, the Niayes zone remains the leading vegetable production area, accounting for 80% of Senegal's production, and is the main supplier of vegetable to major cities such as the capital Dakar. Beyond the supply of vegetables, vegetable cultivation activities constitute a value chain that employs farm workers, carters and transporters, and supplies goods to wholesalers and retailers on the markets. In the Niayes area, overexploitation of the water table by industry and domestic use, combined with climate change, is causing water unavailability problems for vegetable farmers. In the past, the water table in the Niayes area was no more than 5 meters deep. Today, the depth of the water table can reach 12 meters or more in some places [73]. Water scarcity means that vegetable farmers spend more on diesel to draw water. The general aim of this article is to examine the sequential process of adoption of solar pumping systems by vegetable farmers in the Niayes Zone of Senegal.

Following the introduction, the remainder of this paper is organized as follows. First, in section 2, we describe the methodological framework used to carry out the work. Then, in section 3, we will present the results of the research with associated discussions. And finally, in section 4, we conclude the article with a set of recommendations.

2. Methodology

2.1. Sampling Strategy and Sample Size

The latest census "Recensement général de la Population, de l'Habitat, de l'Agriculture et de l'Elevage (RGPHAE)" carried out in 2013 by the "Agence nationale de la Statistique et de la Démographie" or National Agency for Statistics and Demography [74] constitutes the sampling frame and has enabled a breakdown of the number of vegetable farmers according to the four regions that make up the Niayes zone. A systematic random selection was made to select six (6) of the nine (9) that make up the Niayes zone.

The more vegetable farmers and/or a sufficient number of motor-driven pumps for pumping and/or the more public or private intervention for the development of solar pumping systems, the more likely the department is to be chosen. The same is applied to the choice of communes. A total of 401 producers were sampled and interviewed in the field.

2.2. Empirical Specification

The expectation of higher future profits determines technology adoption. The producer will only adopt the new technology if the anticipated profitability is higher than that of non-adoption [75] [76]. If the anticipated utility of the target stage is higher than that of a reference stage, the producer moves from the reference stage to the target stage of the adoption process. For this modelling, we assume the existence of a latent variable y_i^* that depends on a combination of characteristics x_i relating to the producer, the cultivated plot but also the spatial dimension.

Let's assume that the producer's unobserved utility varies according to the stage of the adoption process. Here, adoption follows three stages, and at each stage it is assumed that an unobserved utility, deemed superior, makes it possible to move from the reference stage to the target stage.

Let $\left(y_j^*\right)$, $j = 1, 2, 3$ be an unobserved utility, derived from knowledge of the technology y_l^*, the first test y_2^*, and their continued use y_3^*.

The latent utility y_1^* depends on a vector X_1 of k_1 explanatory variables of technology knowledge and y_2^* depends on a vector X_2 of k_2 variables at the origin of the first test and y_3^* depends on a vector X_3 of k_3 explanatory variables of continuous use of solar energy. Each utility is associated with a binary variable y_i taking either the value 0, 1, 2, and 3.

Then,

$$Y_J = 1,\ if\ Y_J^* > 0,\ j = 1,2,3$$

$$Y_J = 0,\ if\ y_J^* < 0$$

However, the utility y_j^* can only be observed in an individual when the individual has knowledge to the technology, *i.e.* that y_j^* > 0.

Thus, the model is specified as follows:

Technology awareness phase: $Y_{i\,awareness} = 1\ \left[X'_{ij}\beta_{awareness} + \varepsilon_{awareness} > 0\right]$ (1)

Technology test phase $Y_{i\,test} = 1\ \left[X'_{ij}test + \varepsilon_l > 0\right]$ if $Y_{i\,awareness} = 1$

$Y_{i\,test} = 0$ Otherwise (2)

Technology adoption phase $Y_{i\,adoption} = 1\ \left[X'_{ij}adoption + \varepsilon_l > 0\right]$ if $Y_{i\,test} = 1$

$Y_{i\,adoption} = 0$ Otherwise (3)

where β_j et ε_j are respectively the vectors of coefficients to be estimated and of errors.

The conventional approach for this type of model would be to apply the ordered logistic model [77]. However, these decisions are not only ordered but also sequential, as the attainment of one modality is conditional on the attainment of the preceding modalities. Moreover, there is also an aspect of self-selection for each step. Thus, the estimates of the ordered logistic model would be biased as they do not take into account the self-selection effects included in the model [78]. Consequently, the econometric model adapted for this study is the sequential logit model widely used in the literature [79].

3. Results and Discussions

3.1. Statistics on Farmer Socio-Economic and Institutional Factors

These statistics are presented in Table 1. The 401 farmers surveyed, with an average age equal to 38.97 years, are 90% male and 10% female. This is justified by the fact that men are in most cases responsible for the plots or landowners. However, there are more women in the marketing and processing activities not analyzed in this work. Adopters, *i.e.* those currently using solar pumping systems (PVs), are relatively younger than non-adopters, and this could be a determining factor in their decision to adopt them. The average household size of the producers surveyed, estimated at 9.2 individuals, is on average 9.7 members for adopters versus 9 for non-adopters. This small difference in size is significant at the 1% level. With regard to education, for all the producers surveyed, around 46% had attended Koranic school, 30% had at least primary school in formal education, and 23% had no education at all. Here, education takes into account not only formal education but also Koranic schooling, as most producers know how to keep their accounts in Arabic.

In addition, the results show that adopters are better educated than non-adopters. Around 74% of adopters are educated, compared with 70% of non-adopters. Indeed, as the Niayes zone is very close to the big cities, most of these inhabitants have at least attended school, even if only for a year. Access to credit is more marked among adopters than non-adopters. With regard to training, adopters who have received training are almost as numerous as non-adopters.

Concerning the distance of the plot from the market or the main road, the results show that adopters' and non-adopters' plots have the same distances on average.

The method of obtaining land for agricultural activities is essentially dominated by inheritance (66%), followed by sharecropping (20.2%). The predominance of inheritance and sharecropping shows the weaknesses of land tenure security in the area. Indeed, during the focus groups, some producers indicated that the reason they were unable to invest in solar panels was that the land they were cultivating did not belong to them, but to family members. In their view, it's risky to invest in expensive installations, especially in situations where families are at loggerheads over inheritance.

3.2. Perceptions of the Benefits of Solar Installations and the Constraints Associated with Their Use

For the 401 farmers surveyed, the perceived benefits of solar installations are essentially diesel savings for 59% of cases, and improved yields for 22.4%.

With regard to financial constraints, the initial investment is declared to be the main perceived constraint to acquiring solar pumping systems. The high interest rate was the second most important constraint perceived by farmers, accounting for 18.2% of cases, and insufficient subsidy was the third most important constraint, accounting for 12% of cases.

More than half the farmers (56%) identified the fragmentation of farms as the main constraint to installing solar pumping systems, and the presence of saline groundwater as the second constraint (18%). The small area under cultivation was cited in 14% of cases as a constraint to installing solar pumping systems on their plots.

The absence of qualified technicians in the Niayes zone and a lack of knowledge about solar installations were the two main constraints declared by farmers concerning the installation of solar pumping systems.

Constraints related to the operation and maintenance of solar installations are mainly dust on the panels (29% of cases) and lack of technical know-how (22% of cases). However, 35% of farmers indicate that their installations have no maintenance or servicing problems.

3.3. Adoption Results as a Sequential Process

The advantage of the sequential model is that it highlights the causes of abandonment, highlights the key stages for effective adoption, and sheds light on projects and programs to promote renewable energies in order to provide levers to boost adoption.

3.3.1. The First Stage in the Adoption Process: The Factors Determining Producer Awareness about Solar Pumping Systems

With regard to the first stage of the process, factors such as age, marital status, experience, access to credit, the fact that the farmer has noticed climate change in his area, the fact that the farmer is from the Thiès region, the fact that he owns his own home and seniority in the locality were found to be factors influencing the likelihood of the grower being sensitized to the use of solar pumping systems in vegetable cultivation.

The three variables of age, marital status and experience have the same influence on awareness. In fact, younger farmers are more likely to be aware of the use of solar pumping systems than older farmers. On the one hand, during the focus groups, some farmers asserted that young people have the chance to benefit from awareness-raising activities on renewable energies during their school years, as climate concerns have seen a resurgence of interest in recent decades. On the other hand, these young people are involved in vacation or youth activities organized each year by the ministry in charge of youth concerning climate protection. However, the older producers often limit themselves to awareness-raising activities via producers' associations, even though such activities are rare in the Niayes zone.

Access to credit was found to have a negative influence, at the 10% threshold, on the probability to be aware of the use of solar pumping systems. The greater the producer's access to credit, the lower his awareness of solar pumping systems. This surprising result could be explained by the statements made by some producers during the focus groups. It was stated that "producers who have greater access to credit are those who are affiliated to producers' associations". However, affiliated producers are dominated by older producers. During the focus groups in Thiès, an elderly producer stated that "young people are often resistant to associations, which they describe as lacking transparency and internal democracy". This attitude of young people towards associations could translate into difficulties in accessing credit. Following this logic, access to credit could be linked to age. In turn, producers with access to credit are older and less aware. We can always rely on the fact that young people are more aware because they are present on social networks or because they benefit from awareness-raising activities on renewable energies either during their school life, during vacation activities or during the youth activities organized each year by the ministry in charge of youth.

Farmers with some knowledge of changing climate parameters are less likely to be sensitized. This is reflected in the fact that producers with certain skills in terms of understanding climate change may not be too interested in awareness-raising activities.

3.3.2. The Second Stage of the Adoption Process: Factors Influencing the Initial Use of Solar Pumping Systems

With regard to the second stage of the process, *i.e.* the test phase, the results show that age, plot size, distance of the plot from the main road and distance of the plot from the market significantly explain the first use of solar pumping systems. A large area is often associated with large harvests, which could be a source of income for purchasing solar pumping systems. With regard to the distance of the plot from the main road or from the market, the results show that if this distance is small, the probability of testing the solar pumping system increases. The reduction in distance could be an indicator of the management of post-harvest losses. Fewer post-harvest losses means higher yields, making it possible to purchase solar pumping systems. Surprisingly, access to credit does not affect the first use of solar pumping systems. During the focus groups, a good number of farmers stated that many farmers do not have access to credit, and of those who do, few have sufficient funds to make costly investments such as the acquisition of solar pumping systems. However, many farmers with solar pumping systems say they have acquired them thanks to good harvests or through programs to promote solar energy in production systems. Good harvests often explain the acquisition of certain agricultural equipment, but not access to credit.

3.3.3. The Final Stage in the Adoption Process: Factors Influencing the Continued Use of Solar Pumping Systems

Continuous use, which is the last stage in the sequential process of adoption, is explained, according to the results, by gender, experience, household size and access to credit.

Being male explains significantly at the 1% threshold the continuous use of solar pumping systems. This result was found in Senegal by [80], who took adoption as a multi-stage process. This situation could be explained by the fact that men predominate in market gardening activities and hold the land tenure. Indeed, the inheritance system in Senegal confers great advantages on men in terms of plot acquisition compared to women. Given that solar pumping systems are investments that require the availability and security of land, it is easier for a man to install them than a woman.

Older farmers are often described as risk-averse and reluctant to change. Younger farmers, on the other hand, are described as receptive to new technologies and risk-takers. It's worth remembering that in this article, experience is dissociated from age. So, being experienced is not strongly linked to age, even if in most cases, age is often taken as a proxy for experience. During the focus groups, one farmer said "farmers who have benefited from small-scale experiments in the use of solar pumping systems are most often those who succeed in their large-scale use in their plots". This statement strongly supports the finding that, the more experienced the farmer, the more consistently they use solar pumping systems.

Adoption (continuous use) is also significantly influenced by household size at the 5% threshold. Information from focus groups shows that most households, due to difficult access to credit, mobilize resources through solidarity contributions from their members. However, the study by [81] using adoption as a sequential process, finds that the size of the horticultural producer's household has no effect on the continued use of mango fly control techniques in Senegal.

Access to credit does not affect the test of solar pumping systems, but it is a determining factor in their continued use. This is because many producers test just because an opportunity is offered to them by projects or programs promoting solar pumping systems in the agricultural sector. In reality, however, the decision to test is not fully matured or intrinsic to the farmer. The farmer just takes advantage of the opportunity. This explains why some farmers just test and then give up. On the other hand, those who continue to use the technology one or more years after a test are farmers who have matured their orientation towards solar pumping technology, which they often acquire on credit.

Table 1. Descriptive statistics and estimation of the sequential model.

	VARIABLE	**Descriptive statistics**				**Sequential process**		
						Awareness	Test	Adoption
		PV user	No user	Difference	P-value	Coefficient	coeff	coeff
1. Female and 0. Male	sex_female	5.20%	14.20%	−9.00%	0.01	0.719	0.543	-1.541^{***}
						−0.769	−0.393	−0.594
Continuous, number of years	age	38.2	39.5	−1.3	0.37	-0.053^{**}	0.040**	−0.029
						−0.023	−0.015	−0.026
1. If the farmer has received formal education (primary, secondary and tertiary) and 0. otherwise	formal_education	74%	70%	3%	0.47	0.463	−0.021	−0.242
						−0.372	−0.296	−0.506
1. If the farmer is married and 0. otherwise	married	82%	79%	3%	0.52	-0.904^{**}	−0.117	0.046
						−0.457	−0.375	−0.63
Continuous, number of years spent growing vegetables	experience	22.7	20.7	2	0.19	-0.045^{**}	−0.024	0.041^{*}
						−0.022	−0.016	−0.024
1. If the farmer has access to credit and 0. otherwise.	credit_access	37%	21%	16%	0	-0.780^{*}	−0.399	1.177^{**}
						−0.42	−0.298	−0.538

*using solar pumping systems (PVs)

Continued

1. If the farmer is a member of a Farmers' Organisation and 0. otherwise.	**Association member**	**9%**	**7%**	**1%**	**0.61**	**−0.134**	**−0.707**	**0.167**
						−0.513	−0.57	−0.821
1. If the farmer has observed climate change in his zone and 0. otherwise.	Climate Change observations	70%	61%	9%	0.07	−0.549*	−0.078	−0.028
						−0.312	−0.275	−0.419
Continuous, people number in the farmer's household	Household size	9.7	9	0.8	0	−0.087	0.021	0.289**
						−0.091	−0.072	−0.133
1. The farmer lives in the THIES region and 0. otherwise. The THIES region is the region where the most vegetable crops are grown in Senegal.	From THIES region	1%	20%	−19%	0	3.964***	−0.012	−0.09
						−0.616	−0.365	−0.534
1. If a member of the household has received vocational or technical training in vegetable cultivation and 0. otherwise	Training in vegetable cultivation	22%	23%	−1%	0.79	0.584	0.083	−0.268
						−0.411	−0.301	−0.483
1. If the household owns its home and 0. otherwise.	property owner	28%	27%	0%	0.95	−0.958*	−0.077	−0.434
						−0.52	−0.445	−0.703
Continuous, number of years lived in the locality	number of years lived in the locality	28	28.7	−0.7	0.7	0.097***	−0.017	−0.017
						−0.022	−0.015	−0.022
1. If the household received external support and 0. otherwise.	remittance_ reception	90%	93%	−3%	0.37	0.16	0.49	0.113
						−0.618	−0.512	−0.787
Continuous, total expenditure on food, education and health.	Log total expenditure on food	12.6	12.5	0	0.41	−0.06	−0.007	−0.886
						−0.444	−0.488	−1.066
1. If at least one member of the household (other than the farmer) works on the plots and 0. otherwise.	intervention	9%	15%	−6%	0.11	0.183	0.138	−0.518
						−0.434	−0.447	−0.716
1. If inherited and 0. otherwise.	inherited	69%	65%	3%	0.49	−0.547	0.238	0.189
						−0.451	−0.36	−0.529
Continuous, number of hectares under cultivation	Farm size	25%	24%	1%	0.63	−0.05	0.044**	0.477
						−0.045	−0.022	−0.997

Continued

Continuous, total amount allocated to the purchase inputs	**log_inputs cost**	**9.5**	**10**	**−0.5**	**0.3**	**0.056**	**0.023**	**−0.011**
						−0.053	−0.027	−0.048
Continuous, number of km separating the plot from the main road.	Distance from main road	1.7	1.6	0.1	0.62	0.203	−0.215*	−0.251
						−0.13	−0.129	−0.208
Continuous, number of km plot from the nearest market	Distance from market	7.5	7.5	0	0.98	0.431	−1.401*	−0.051
						−0.684	−0.768	−0.047
	Constant					−1.578	−1.314	11.407
						−5.495	−6.131	−13.054
	Observations					401	401	401
	Wald chi2					126.9	126.9	126.9
	Prob > chi2					0	0	0

Robust standard errors in parentheses

***p < 0.01, **p < 0.05, *p < 0.1

4. Conclusions

The aim of this article is to analyze the determinants of the adoption of solar pumping (PV) systems by vegetable farmers in the Niayes area of Senegal. A global sample of 401 farmers was used. Instead of considering the adopter as a producer who indicates whether or not he or she uses the technology (binary choice), we considered the adopter as someone who knows about the technology, tests it and uses it on an ongoing basis. The results indicate that age, marital status, experience, access to credit, knowledge of climate change, origin of the farmer in the Thiès region and seniority in the Niayes zone are the main variables influencing knowledge of the use of solar pumping systems (PV). As for the first use of PV, it is determined by variables such as plot size, distance of the plot from the main road or from the market. Surprisingly, access to credit had no impact on the initial use of solar pumping systems. Finally, adoption or continued use is influenced by gender, experience, household size and access to credit. Access to credit does not affect the first use of solar pumping systems, but it is a determining factor for their continued use.

The study led to the following economic policy recommendations: i) An awareness-raising and education campaign would raise people's awareness of the benefits of solar pumping systems in reducing greenhouse gas emissions and improving crop productivity; ii) Extending renewable energy development and promotion programs into productive sectors would improve producer performance and reduce poverty; iii) Setting up support services and involving women would enable the full agricultural potential of the Niayes region to be exploited.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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