Explaining drivers of farmers' willingness for early adoption of enhanced irrigation technologies: Case of Tunisia

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Abstract

The objective of this paper is to identify the influencing factors of farmers' willingness for early adoption of enhanced irrigation technologies in Tunisia. We estimate a multinomial logit model with data from 931 farmers in Central (Chebika) and Northern (Fernana) of Tunisia. Regression results reveal that early adoption is positively influenced by levels of extension service quality, trust in farmers' associations and extension agents, farmer's perception towards the innovation, credit access, and off-farm income. However, it is negatively affected by market access issues, risk aversion, and age. Risk, trust, and perception towards technology are important factors in driving early adoption decision. The findings imply that farmers training on water conservation technologies, financial support for innovation adoption, awareness of young farmers about the opportunities of agricultural innovation, incentives to farmers' associations in order to improve their market access, and inclusive participatory approaches during technology generation and transfer are all accelerators of early adoption of innovations by farmers.

Keywords*: Early adopters, Enhanced irrigation technologies, Multinomial ordered model, Drivers of early adoption, Tunisia.*

1. Introduction

Agricultural innovation is crucial for increasing agricultural productivity, food security, conservation of natural resources, and alleviating poverty. Adoption rate and speed to adopt determine the ultimate impact of agricultural innovation on these indicators. Speed of adoption is the time from the date of innovation introduction to adoption. Innovation spread within temporal involves different states and types of adopters (innovators, early adopters, early majority, late majority, and laggards). Innovation adoption decision is a process which includes: knowledge, persuasion, decision, implementation and confirmation (Rogers, 2003). In fact, farmers do not accept innovation immediately, they need time to think things over before making decision.

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In Tunisia, some studies were carried out to analyze the adoption decisions of agricultural innovation (Aziza *et al.*, 2009; Fouzai *et al.*, 2018; Dhehibi *et al.*, 2018; Dhraief *et al.*, 2019; Dhehibi *et al.*, 2020; Dhehibi *et al.*, 2022). The majority of these studies showed that agricultural innovation promotion is characterized by low rate of adoption. However, to our knowledge, no studies tackled the early adoption of agricultural innovation in Tunisia. Early adoption of innovation adoption is usually required, since it can improve overall agricultural productivity and reveal the resilient farming systems (Batz *et al.*, 2003). Early adopters can lead to quickened diffusion of innovation because they take less time to adopt innovation than late adopters. The concept of 'early adopter' has become common in agricultural science since the Eightees (Lindner *et al.*, 1982; Bultena and Hoiberg, 1983; Korsching *et al.*, 1983; Byerlee and De Polanco, 1986). The identification of early adopters of enhanced irrigation technologies is especially important in current water scarcity, climate change and drought circumstances. Therefore, the main objective of this paper is to identify the major factors influencing farmers' willingness for early adoption of enhanced irrigation technologies in Northern and Central Tunisia.

2. Conceptual framework

The assumption of utility maximisation is generally used to explain farmers' adoption decisions of new technology (Adesina and Zinnah, 1993; Alcon *et al.*, 2011). Under this assumption, a farmer will adopt a given technology if the utility obtained from the new technology exceeds that of the old one. For example, farmers will adopt new irrigation system if their expected utility, subject to their preferences and constraints (e.g., time and climate), is maximized by doing so. Utility is a function of various factors including expected benefits and costs of adopting a practice versus not adopting. Several factors that condition farmers' adoption decisions have been discussed and can be divided into five categories as indicated in Figure 1: (1) Farmers' characteristics, (2) Farm characteristics, (3) Farmers' behavior and perception, (4) Technology characteristics, and (5) Institutional and communication factors. These categories and explanatory variables are based on the literature related to early adoption studies of agricultural technologies (Alcon *et al.*, 2011; Beyene and Kassie, 2015; Kassie *et al.*, 2015; Manda *et al.*, 2020; Ngango and Hong, 2021; Kumar *et al.*, 2021; Ayisi *et al.*, 2022; Tey and Brindal, 2023).

The most studied factors in the first category are age, education, gender and experience of the farmer. The second category is factors relating to the farm characteristics which include variables such as location, farm size, land tenure, off-farm income, etc. A third category of factors is the farmers' behavior and perception including variables such as the trust in extension agents and farmers' associations, risk attitude, time preferences, etc. The fourth category is the innovation characteristics (relative advantage). More specifically, the degree to which the new tech-

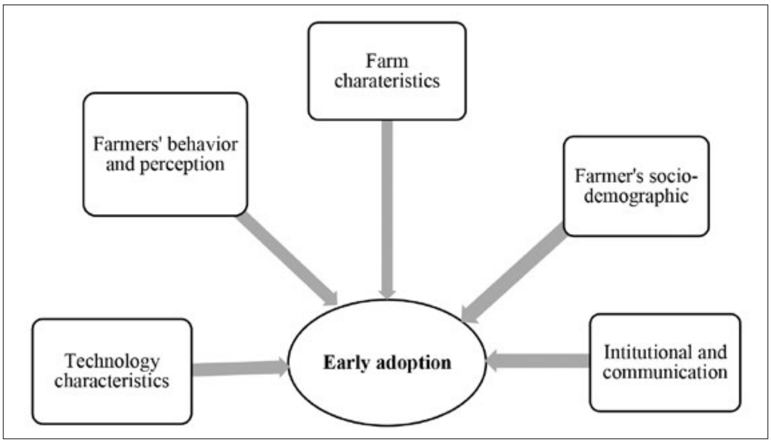
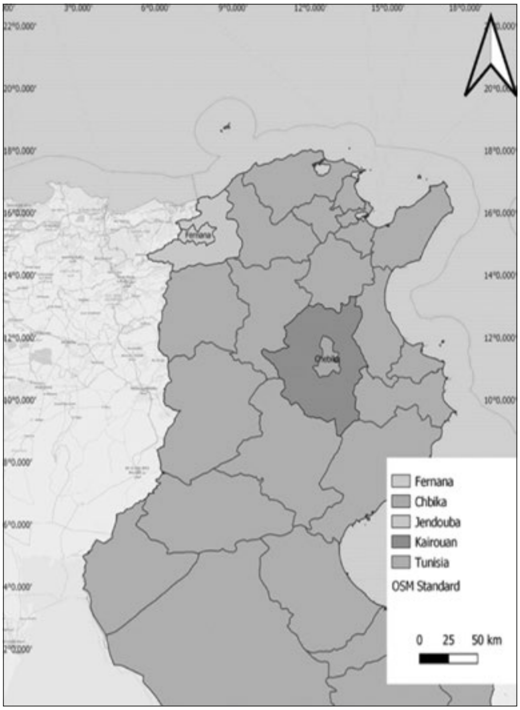


Figure 1 - Factors affecting early adoption of agricultural innovation among farmers.

Source: Own elaboration.

Figure 2 - Geographical locations of study areas.



nology is believed by farmers to perceive better as the one it will replace (perception regarding innovation). Finally, the fifth category including institutional and communication factors such as assistance from extension services, credit access, and market access.

3. Methodology

3.1. *Study area and data collection*

The data used for the empirical analysis was obtained from a farm survey conducted in September-October 2021 by the FoodLAND project Team in collaboration with extentionists. The survey covered two study areas indicated in Figure 2 (Fernana in the North and Chebika in the Center of Tunisia). Chebika is located in the governorate of Kairouan. It is a semi-arid area with an annual average rainfall of about 290 mm. This average varies between 250 and 400 mm. The main crops cultivated in the area are: wheat, vegetables (especially tomato and chilli pepper), and olive trees. These crops are mostly grown under irrigated conditions. Both surface (Houareb dams) and groundwater resources (deep and shallow aquifers) are available for irrigation in Chebika. However, Fernana is a sub-humid area with mean rainfall of 700 mm. Cereals under rainfall conditions are the dominated crops in this area. The stratified sampling by farm size was used to select 713 and 218 farmers in Chebika and Fernana, respectively. The total number of farmers in Chebika and Fernana are around 5000 and 2000, respectively. The questionnaire used for data collection includes questions about the context of farm, resources and technology, farm production, farmers' perception, and farmers' characteristics.

3.2. *Empirical model, variables used and hypotheses*

We categorized adopters based on their responses to the question, "To what extent would you consider introducing enhanced irrigation technologies on your farm?" The Likert scale used had the following options:

1. Not interested;
2. Interested if more than half of the farmers adopt;
3. Interested if at least half of the farmers adopt;
4. Interested if at least some of the farmers adopt;
5. Willing to be one of the first in my village.

We classified respondents who chose options 4-5 as early adopters, options 2-3 as late adopters, and option 1 as non-adopters. The dependent variable defines the type of adopters according to the speed of innovation adoption (early, late and no adoption) with an ordinal categorical nature. That's why a multinomial ordered logit model will be used to identify the factors influencing farmers' willingness early to adopt new agricultural technologies.

The ordered logit model is based on the following specification. We suppose that unobservable variable $Z_i = x_i'\beta + \varepsilon_i$ exists, related with the explanatory variable and affects the result of observable variable Y_i as follows:

$$Y_i = j \;\; if \quad \mu_{j-1} < Z_i < \mu_j \qquad (1)$$

We define the multinomial ordered model in the following way:

$$P(Y_i = j) = F(\mu_j - x_i'\beta) - F(\mu_{j-1} - x_i'\beta) \qquad (2)$$

i=1 , 2,……n;   j=0,1,…..m

The functional form of F most frequently used in application is logistic:

$$Logit \quad F(Z) = \frac{e^Z}{1+e^Z} \qquad (3)$$

Where $Z = x'\beta \qquad -\infty < Z < +\infty$

The explanatory variables included in the model are farm location, farm size, age of farmer, education level of household head, risk attitudes and trust in other farmers and extension agents, access to extension services, land tenure, access to credit, market access, off-farm income and perception towards enhanced irrigation technologies. The definitions of the variables and hypotheses are presented in Table 1.

Since we have only three groups in our example, the model (1) is simplified and presented as follows:

$$\begin{aligned} Y_i &= 0 \quad if \quad Z_i \leq \mu_0 \\ Y_i &= 1 \quad if \quad \mu_0 \leq Z_i \leq \mu_1 \\ Y_i &= 2 \quad if \quad Z_i \geq \mu_1 \end{aligned} \qquad (4)$$

Where: U_i unobserved thresholds defining the group;

$$Z_i = x_i'\beta + \varepsilon_i$$

Zi= B0+ B1 Age + B2 EL + B3 Gender + B4 Location + B5 Size + B6 Tenure + B7 Off-farm + B8 Pertec + B9 Risk + B10 Trust + B11 Extension + B12 Credit + B13 Market + εi

Table 1 - Variables used in the ordered logit model and hypohetized sign.

Variable	*Description*	*Nature of quantification*	*Hypothetised sign*
Dependent variable	Types of adopters	0 not interested in adopting, 1 interested to be late adopters, 2 interested to be early adopters	
Independent variable			
Demographic characteristics			
Age	Age of farmer	number of years	+/-
EL	Education level	1 higher than primary level, 0 otherwise	+
Gender	Sex of the household head	1 male, 0 female	+/-
Farm characteristics			
Location	Chebika/Fernana	1 chebika / 0 fernana	+/-
Size	Farm Size	number of ha	+
Tenure	Land tenure	1 property, 0 otherwise	+/-
Off-farm	Off-farm income	1 yes / 0 No	+
Technological factors			
Pertec	Perception towards enhanced irrigation benefits	1 positive perception, 0 otherwise	+
Perception and behavioral factors			
Risk*	Risk attitudes	1 aversion, 0 otherwse	-
Trust*	Trust in farmers and extension agents	1 trust, 0 otherwise	+
Institutional and communication factors			
Extension services*	Assistance from extension services	1satisfied, 0 no	+
Credit	Credit access	1 yes / 0 No	+
Market*	Market access issues	1 no problem, 0 otherwise	-

** Likert scale is used from 1 to5 for data collection of these variables. We combined 1-3 as a base of disagree and 4-5 as an agree variable.*

4. Results and discussion

The Variance Inflation Factor (VIF) between the independent variables does not exceed 4, rejecting the hypothesis of multicollinearity. The results of Durbin-Wu-Hausman test of endogeneity show that we can accept the null hypothesis of no endogeneity of risk and trust variables because the p-value is higher than 0.05, indicating that these variables are not correlated with the error term. Empirical results are reported in Table 2. The coefficients of the two thresholds (u0 and u1) are statistically significant at 5% level. The likelihood ratio (LR) is also statistically significant at 1% level, indicating a good fit of the model.

Regression results of multinomial logit model reveal that early adoption is significantly and positively influenced by extension services, trust, perception towards innovation, credit access and off-farm income. However, it is significantly and negatively affected by market access issues, risk aversion, and age. Gender, farm location, farm size and education level of household head have no significant influence on early adoption decision of enhanced irrigation technologies.

The positive and significant association between extension services and early adoption shows that farmers who are satisfied from the assistance of extension services are more likely to be early adopters of enhanced irrigation technologies. This result is in line with previous studies (Daberkow and Mcbride 1998; Diederen *et al.*, 2003; Dadi *et al.*, 2004; Llewellyn, 2007; Beyene and Kassie, 2015; Deepak *et al.*, 2019).

The results also reveal that trust is significantly and positively affecting the early adoption decision. This result indicates that farms who trust other farmers and extension agents are more likely to be early adopters. This finding is similar to findings of Beyene and Kassie (2015) and Ainembabazi *et al.* (2016), and Deepak *et al.* (2019).

Furthermore, the results in Table 2 show that the perception towards innovation is significantly and positively associated with early adoption decision. This result is in agreement with the findings of Adesina and Zinnah (1993), Batz *et al.* (1999), Llewellyn and Brown (2020), Zhllima *et al.* (2021) and Nyairo *et al.* (2022).

Additionally, the financial variables such as off-farm income and credit access have a posi-

Table 2 - Maximum likelihood estimates of the ordered logit model of farmers' willingness to early adopt agricultural innovation.

Variables	*Coefficient*	*t-statistic*	*Marginal effects for early adopters*
Age	-0.153**	-2.46	-0.003**
EL	-0.160	-0.10	-0.031
Gender	-0.017	-0.97	-0.003
Location	-0.078	-0.40	-0.015
Size	-0.002	-0.23	-0.001
Tenure	-0.029	-0.13	-0.006
Off-farm	0.435*	2.48	0.083*
Pertec	0.429**	2.68	0.082**
Risk	-0.909***	-5.42	-0.174***
Trust	0.562***	3.56	0.108***
Extension	0.715***	3.74	0.1370***
Credit	0.383*	1.68	0.073*
Market	-0.461***	-3.07	-0.0883***
U_1	-2.219**		
U_2	-0.687**		
Log-likelihood	-708.305***		

**** significant at 1%; ** significant at 5%, * significant at 10%.*

tive and significant effect on early adoption decision. This paper thus confirms that financial variables play significant roles in the decision to early adopt enhanced irrigation technologies. Our results are in keeping with the findings reported in the speed adoption literature that identifies early adopters (Daberkow and Mcbride, 1998; Ayisi *et al.*, 2022).

The age of household head has a negative and significant influence on early adoption decision. This implies that older farmers are less likely to be early adopters. This result is in line with findings reported by Daberkow and Mcbride (1998), Diederen *et al.* (2003) and Ayisi *et al.* (2022).

As expected, table 2 further indicates that market access issue has found to be important driver of early adoption. This result is in line with the findings of Dadi *et al.* (2004) and Matuschke and Qaim (2008) who demonstrated that lack of market access is one of the major constraints affecting the adoption of enhanced irrigation technologies.

Finally, the results also indicate that risk aversion affect negatively and significantly early adoption decision. The finding is consistent with the empirical literature that identifies early adopters (Yoo, 2014; Finger and Möhring, 2022). In fact, risk takers farmers are more likely to be early adopters of agricultural innovation compared to risk averse farmers.

Marginal analysis shows that risk, trust, market access, extension services, and perception towards technology are important factors in driving early adoption decision. Therefore, to accelerate the adoption speed of enhanced irrigation technologies by farmers in Tunisia, especial attention should be given to these factors. This could lead enhancement of agricultural productivity sector.

5. Conclusion and policy implications

This paper identified the major factors influencing farmers' willingness for early adoption of enhanced irrigation technologies in Northern (Fernana) and Central (Chebika) of Tunisia. The paper used a multinomial logit model for the empirical analysis of the collected data from a survey conducted to 931 farmers.

The identification of early adopters of enhanced irrigation technologies is especially important in current water scarcity, climate change and drought circumstances. The results highlight that farmers' perceptions and attitudes should be considered in the analysis of adoption studies.

Farmers with financial availability, those who trust extension agents and farmers' association, risk takers, young, satisfied from the assistance of extension services and without market access issues are more willing to be early adopters of innovation. The findings imply that following interventions can accelerate the adoption speed of farmers in Tunisia:

- Farmers and extension officers training on water conservation technologies is highly recommended;
- Farmers should be provided with mechanisms of financial support for innovation adoption such as subsidy for access to credit;
- Increase awareness of young farmers about the usefulness and opportunities of agricultural innovations;
- Participatory approach including all stakeholders during technology generation and transfer should be implemented;
- Provide incentives to farmers' associations in order to improve their market access;
- Inform farmers about the advantage of innovation through trials, field days, information and communications technology, etc.

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