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Factors Influencing Farmers' Decisions to Adopt Improved Technologies in Semi-Arid Farming Systems: A case study of the barley variety Kounouz and feed blocks technology in Tunisia

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List of Acronyms

CRDA	Commissariat Régional au Développement Agricole
CTV	Cellule Territoriale de Vulgarisation
GDP	Gross Domestic Product
ICARDA	International Center for Agricultural Research in Dry Areas
INS	Institute National de la Statistique
ML	Maximum Likelihood
RCT	Randomized Control Trials
SPSS	Statistical Package for Social Science

KEY MESSAGES

Abstract

Despite the high potential of innovative agricultural technologies to boost productivity, incomes, and food security for farmers, the adoption rate by smallholders in Tunisia's livestock-barley systems is very slow. This paper aims to understand the main factors that influence farmers' decisions to adopt the improved barley variety *Kounouz* and livestock feed blocks in Tunisia. This study presents an analytical framework that combines both extrinsic and intrinsic factors that affect farmers' decision-making to adopt new agricultural technologies and applies the framework to Kounouz and feed blocks as a case study. A quantitative approach employing a cross-sectional design was used to gather data. Stratified random sampling was employed and a total of 671 small-scale farmers were selected. Data analysis and assessment was done through descriptive and statistical inferential analysis, and econometric modeling using the binary logistic regression model. The results show that the uptake of agricultural technologies is a complex process influenced by both extrinsic and intrinsic variables.

The innovation characteristics like the perceived benefits of the technology, the knowledge needed to use the technology, the payment and availability of inputs and resources have major influence on the adoption of Kounouz and feed blocks by smallholders. To a lesser extent, the characteristics of the farmer affect adoption indirectly by influencing their knowledge, attitudes, and perceptions, which in turn influence their decision-making. The characteristics of the external environment have a moderate and high influence for adopting Kounouz and feed blocks respectively. For the communication and extension dimension, the distance to the extension office negatively affects farmers' decisions for adopting Kounouz. To improve the adoption of both technologies in the study area, policy makers should understand the knowledge and attitudes farmers have in relation to these technologies and how these are brought to them. Drawing on this information, policies, agricultural technologies and their related extension activities can be redesigned to be appropriate for the preferences and specific conditions of farmers, leading to greater and more sustainable adoption.

Keywords

Kounouz; barley; feed blocks; livestock; adoption; attitude; knowledge; perception; analytical framework; binary regression; decision-making; Tunisia.

Highlights

- The uptake of the improved barley variety Kounouz and livestock feed blocks is a complex process influenced by both extrinsic and intrinsic variables.
- The innovation characteristics like the benefits perceived, knowledge needed, payment, and availability of inputs and resources have major influence on the adoption of Kounouz and feed blocks by smallholder farmers.
- To improve the adoption of Kounouz and feed blocks in the study area, agricultural policy makers should understand the knowledge and attitudes farmers have in relation to these technologies and how they are brought to farmers.
- This information can be used to redesign policies, technologies, and extension activities to be more appropriate for farmers' preferences and specific conditions, leading to greater adoption and lasting impact.

1. INTRODUCTION

In Tunisia, livestock represents 4 percent of the country's GDP and contributes 41 percent of the nation's total agriculture production (INS, 2016). Livestock are mainly kept by resource limited smallholders, with nearly 80 percent of rural populations and most farmers relying on traditional methods of production –¬ a factor that has lowered the level of productivity. The Tunisian livestock sector plays a critical role in food systems and faces emerging global challenges related to climate change and market volatility.

The introduction of agricultural technologies into farmer production system brings numerous benefits. Feed blocks provide flexibility to livestock farmers, allowing them to choose the ingredients to be included in the feed block and providing a food supplement in drought and other harsh conditions. In addition, the blocks can be prepared when the cost of the ingredients is low and stored for later use. Additionally, the introduction of the improved barley Kounouz into farmer production systems increases production at the farm level, improves soil quality especially nitrogen content, and provides a source of fodder for farmers. Compared to traditional crops, improved barley varieties significantly boost yields.

Despite the potential of agricultural technologies to increase productivity, incomes, and food security, the adoption rate by the smallholder farmers in Tunisia's livestock-barley systems is low. This 'adoption gap' is not only observed in the case of Tunisian innovation adoption but is typical for agricultural system innovations and natural resource management technologies in developing countries in general (Noltze et al. 2012). Improving agricultural productivity plays a key role in maintaining livelihoods and ensuring a robust food supply to sustain national development and growth.

Previous research studies conducted in different areas of Tunisia suggest that economic, socio-demographic, institutional, and technical factors have influential roles in farmers' decisions related to the adoption of innovative and improved agricultural technologies, such as the case of seeding on plant cover (Ben Salem et al., 2006), technical and organizational innovations (Mohamed et al., 2009), soil and water conservation technologies (Dhehibi et al., 2018), and conservation agriculture technologies (Fouzai et al., 2018). However, the literature is scarce when assessing factors influencing the adoption of livestock-related improved technologies. There is little information available on the following technologies: feed blocks, cactus choppers, automatic-waterers, solar milk cooling systems, improved rams, and improved barley varieties in Tunisia (Dhraief et al, 2019).

The objective of this study is to better understand the linkages between the adoption of the improved barley variety Kounouz and livestock feed blocks by Tunisian smallholder farmers in 2018, and the following aspects: (1) extrinsic and intrinsic factors related to the characteristics of farmers such as socio-demographic and economic factors; (2) the characteristics of the external environment like access to infrastructure and climate change; (3) the characteristics of the agricultural innovations such as the perceived benefits, knowledge required, access to the technology, adoption cost, and availability; and (4) communication and extension factors. This study allows researchers, policy and decision makers to better understand the implications and influence that these factors have in the adoption decision-making process by smallholder farmers. This information can be used to design more effective agricultural technologies, extension systems and policies that lead to higher adoption rates and greater long-term benefits for farming families.

Several research questions emerge from this study:

- How can the adoption of innovative technologies by smallholder farmers be increased?
- What effect do the personal characteristics of the farmer have on their decisions to adopt agricultural innovations?
- To what extent does the external environment influence the adoption of agricultural innovations?
- To what extent do the characteristics of agricultural innovations influence the adoption of the innovations?
- How can smallholder farmers be better connected with sources of knowledge, such as extension services, other farmers, etc.?

The remaining sections of the paper are organized as follows: Section 2 reviews literature on the topic; Section 3 describes the methodological framework of the study with emphasis on the study area, data collected, and the empirical model; Section 4 presents the results and discussion of the main findings; and Section 5 delivers concluding remarks.

2. THEORETICAL FRAMEWORK: THEORY OF DECISION-MAKING

The decision-making process in agriculture is complex, as many factors and a multifaceted environment influences farmer in their decision-making approach. Bradford (2009) describes the farming environment as complex and uncertain due to aspects of various origin, such as the pressure of being economically or environmentally successful and the uncertainty of outer influences, like weather or political frameworks. Furthermore, farmers can be influenced by their surrounding and the information given by the community (Ibid.). Another essential influence in the decision-making of a farmer are lessons learned from the past and possible recovery processes (Ibid.).

Many studies that have investigated farmers' decision-making have used a normative theory approach which is focused on economic factors and that farmers strive for profit maximization (e.g. Gould 1963; Howes 1967). The advantages of this theory are that it enables economic modelling of behavior and that it can potentially predict behaviors (Binswanger 1980). However, it is important to mention that farmers not only make decisions according to the economic outcome but are people who live in an environment with specific circumstances. They can be influenced by their direct and indirect environment, by their family or community, or by traditions and experiences.

More recently, the research on decision-making in agriculture has focused on a naturalistic decision-making framework, which includes a descriptive approach. Klein et al. (1993) describe a decision maker, in the context of agriculture and naturalistic theory, as someone who is street-smart and a hands-on practitioner who relies on experiences in order to find solutions. The decision maker makes accurate assessments of situation, classifies, and interprets problems based on knowledge and experience and decides on the best option (Ibid.). Naturalistic decision-making can help to complete normative research through cognitive processing and observations (Bradford 2009). Personal factors like values, attitudes, and norms are considered in these studies in order to understand context of societies (Ibid.).

The degree of adoption of any innovative technology depends largely on its characteristics. Rogers (1961) identified five characteristics that affect the rate at which an innovation is adopted: relative advantage, compatibility, complexity, divisibility (triability), and communicability (observability). According to Rogers (1995), farmers may learn from their own experimentation, from agricultural extension services in the area, and from neighboring farmers. In the case of developing countries, farmers often learn through the social learning approach. Rogers (2003) has drawn attention to an adoption category based on the innovation decision period. The innovation decision period is the length of time required to pass through the innovation decision process.

Another way of looking at decision-making was developed by Fishbein and Ajzen (1975) and is called the 'theory of reasoned action'. It is an expectancy-value model with emphasis on attitudes, subjective norms, intentions, and behaviors directed at a specific focus. Expectancy-value models provide a framework for understanding the relationship between a person's attitudes and their underlying beliefs. This theory includes a third component, the perceived behavioral control, which predicts the behavioral intention. Together, the attitude towards the behavior, the subjective norms and the perception of behavioral control lead to the formation of a behavioral intention, which in turn leads to the performance of the behavior (Ajzen 1991). Even though the theory is fairly reductionist and consequently has been the target of much criticism and debate over the years, it has become one of the most frequently cited models for the prediction of human behavior (Ajzen 2011).

2.1. Explaining decision-making: An analytical framework

Given that technology uptake is a complex nonlinear process influenced by multiple factors, the use of a single theory in analyzing decision-making could not provide a full picture of the adoption process (Meijer et al. 2014). A comprehensive framework which considers the interaction of various factors in decision-making is needed. The role of knowledge, perceptions, and attitudes are at the center of the analytical framework used in this study (see Figure 1). The knowledge and perceptions about an innovation together determine the attitude towards it. In accordance with the theory of planned behavior, the attitude component comprises not only the attitude towards the behavior, but also the attitudes regarding the subjective norms and perceived behavioral control. In this case, we expect that a positive attitude towards an agricultural innovation will increase the likelihood of adoption and a negative attitude will reduce the probability of adoption (Ibid).

There are a large number of extrinsic variables which help shape knowledge, attitudes, and perceptions. The extrinsic variables can be grouped into three categories: (1) characteristics of the farmer; (2) characteristics of the external environment; and (3) characteristics of the innovation. The role of extension and training are crucial in the development of knowledge, perceptions, and attitudes about agricultural innovations (Ibid).

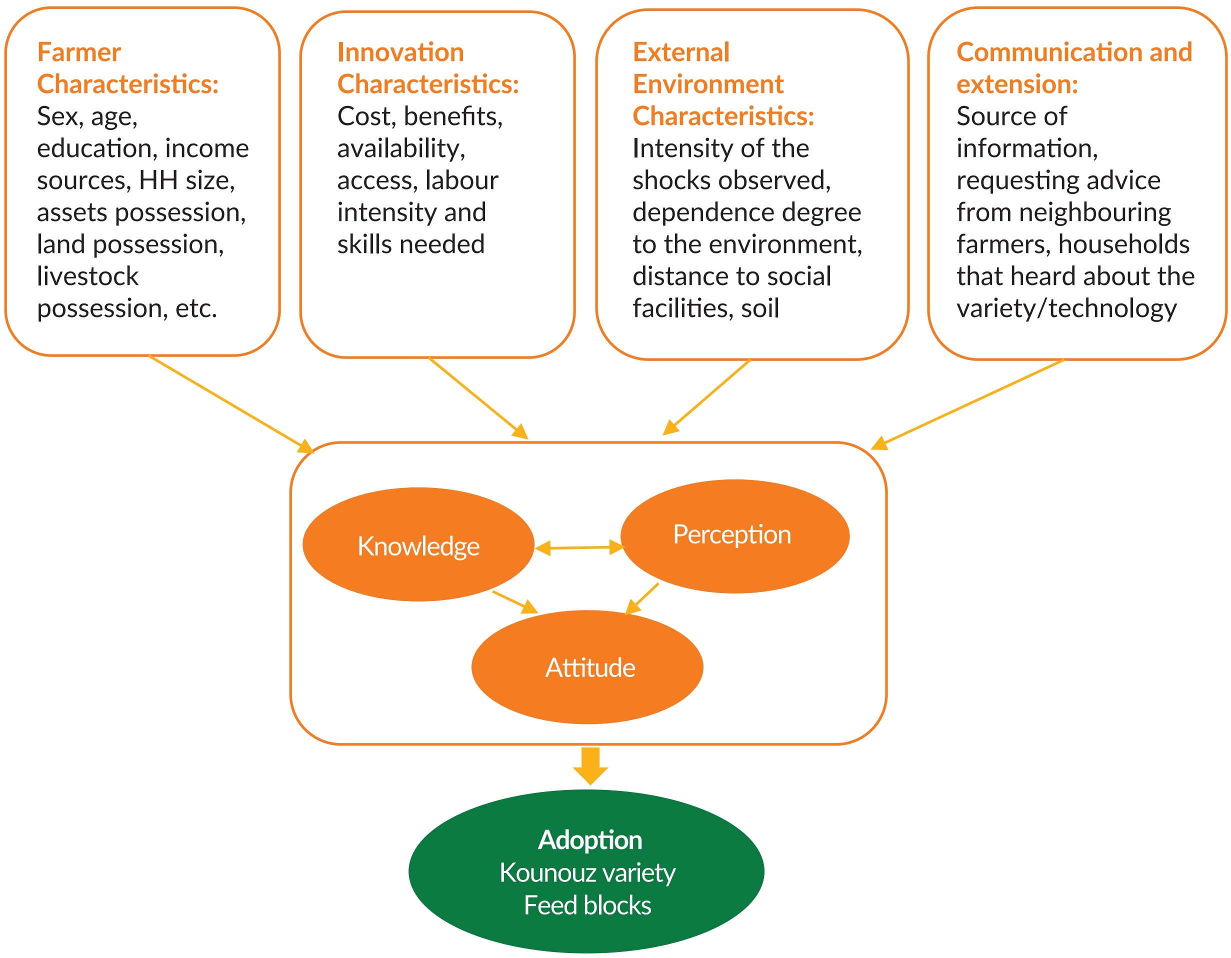

Figure 1. Conceptual framework showing the linkages and interaction between the characteristics of farmers, innovations and external environment and the influence of communication and extension variables in the decision-making process of adoption of Kounouz and feed blocks in 2018.

Source: Own elaboration based on Meijer et al, 2014.

3. METHODOLOGICAL FRAMEWORK

3.1. Study Area

The 'Mind the Gap' project on which this study is based, works in two governorates with similar agro-ecological conditions: Zaghouan and Kairouan. Zaghouan governorate is located in North East Tunisia. It is bordered by the governorates of Ben Arous, Ariana and Manouba to the north, Sousse and Kairouan to the south, and Siliana and Beja to the east. It covers an area of 2820 km2 and it is characterized by a semi-arid climate with an average annual rainfall of 450 mm. Kairouan governorate is located in Central West Tunisia. It has a privileged geographical position since it represents a crossroads between the north, the south, the east, and the west of the country. It is bordered by the governorates of Zaghouan, Siliana, Kasserine, Sidi Bouzid, Sfax, Sousse, and Mahdia. It covers an area of 6712 km2, and it is characterized by an arid climate in the south and semi-arid climate in the north. Average rainfall ranges from 200 mm in the south to 350 mm in the north (see Figure 2).

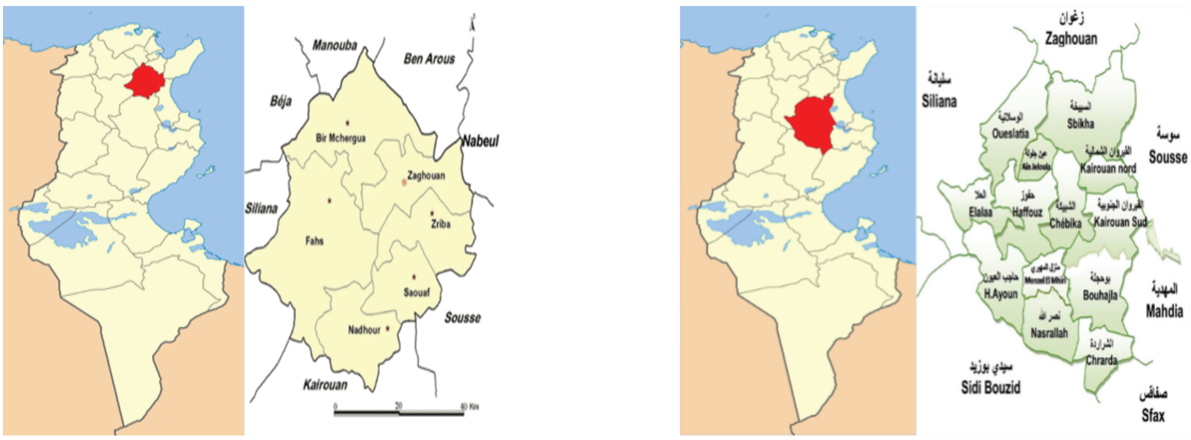

Figure 2. Map of the study site in Tunisia.
Source: Author's elaboration (2019).

3.2. Data Collection

Data for the impact analysis were collected through a follow-up survey (after implementation of the treatment groups) conducted in December 2018. The questionnaire was divided into 17 modules covering all the variables that can influence the adoption of agricultural technologies by smallholder farmers. Module 0, Module A, and Module B focused on the identification of the households with questions related to demographic data and the characteristics of the main house. Modules C and D focused on household assets, and questions included land owned, land title possession, cost of renting land, and access to communal pasture. Module E focused on crop management and questions included quantity, price, and source of inputs. Module F, Module H, and Module G Focused on livestock possession, marketing, technology, and nutrition with questions including feed calendar, number of animals sold, and the number of communications with a veterinarian.

Module I and Module J focused on technology perception and the awareness and adoption of technologies by households. Module K focused on the social networks of households with questions including knowledge, number of contacts, and distance to neighbors. Module L and Module M focused on the other sources of income, and income transfer, and non-food expenditure. Module N focused on access of the household to socio-economic infrastructure with questions centering on the distance to the nearest social facilities. Module O and Module P focused on system vulnerability and dietary quality with questions including shocks observed, coping strategies, quantity, and amount of food consumption. The findings of the survey are presented using descriptive statistics based on frequencies and percentages. Statistical analysis was performed with SPSS Version 22.0 statistic software package. The analysis concerned a total sample of 671 households divided between 454 in Kairouan and 217 in Zaghouan.

3.3. Analytical Framework

3.3.1. Randomized Control Trials (RCT) Method

The 671 female and male farmers who participated in the experiments have received specific improvements related to the access to technical training and subsidized inputs, access to economical and organizational training, and female empowerment. These three components were combined in various ways, and the combinations were implemented in different treatment groups to test and compare their individual and combined effects. By using RCT, the project aimed to discover which agricultural extension design best favors the adoption of the improved barley variety Kounouz and the feed blocks technology within smallholder farmers.

Table 1. Distribution of project households according to the treatment groups (T) in 2018

T1 (N=137)	T2 (N=137)	T3 (N=137)	T4 (N=131)	Control(N=129)
Technical training	Technical training Econ/organizat. training	Technical training Econ/organizat. training Female empowerment	Technical training Female empowerment	None

Source: Own elaboration from project data (2019).

3.3.2. Binary Logistic Regression Method: Logit model

Modeling a relationship between the decision to adopt and not to adopt an innovative technology with the observed factors requires the use of qualitative response models. Commonly used models of this type are probit (which assumes an underlying normal distribution) and logit models (which corresponds to a logarithmic distribution function). Both the logit and probit models yield similar parameter estimates and it is difficult to distinguish them statistically (Aldrich and Nelson 1984). The logit model was used in this study since it is easier and simpler to interpret and thus has been widely applied in adoption studies (Ng'ombe et al. 2014; Akrouch et al. 2017). The adoption decision by farmers is specified as:

$$Z_i = \beta_0 \sum_{i=1}^{n} \beta_i + \beta_i X_i, \dots \dots \dots (1)$$

Where β_0 is a constant and Z_i is equal to one (1) when a choice is made to adopt and zero (0) otherwise. This means that the equation represents a binary choice model involving the estimation of the probability of adoption of a given technology (Z) as a function of independent variables (X). Mathematically, this is represented as:

$$\mathrm{Prob}(Z = 1) = F(\beta' X_i) \quad (2)$$
$$\mathrm{Prob}(Z = 0) = F(1 - \beta' X_i) \quad (3)$$

Where, Z_i is the observed response for the i^{th} observation of the response variable, Z. This means that $Z_i = 1$ for an adopter (i.e. farmers who adopt modern agricultural production technologies) and $Z_i = 0$ for a non-adopter (i.e. farmers who do not adopt modern agricultural production technologies). X_i is a set of independent variables such as farm size, family size, education of household head, among others, associated with the i^{th} individual, which determine the probability of adoption (P). The function may take the form of a normal, logistic or probability function. The logit model uses a logistic cumulative distributive function to estimate, P given z by:

$$\Pr(Y = 1/X) = \frac{e^z}{1+e^z} \quad (4)$$

$$\Pr(Y = 0/X) = 1 - \frac{e^z}{1+e^z} \quad (5)$$

$$Z = \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_K X_K = \sum_i^k \beta_i X_i \quad (6)$$

Where, k represented the number of independent variables to be analyzed in the study. Since the model is non-linear, the parameters are not necessarily the marginal effects of the various independent variables. The maximum likelihood method was used to estimate the parameters. The empirical model for the logit model estimation is specified as follows:

$$Z_i = \ln\left(\frac{P}{1-P}\right) = \alpha + \beta_i X_i + \delta_i \quad (7)$$

The above formula is called log of odds ratio and Xi is the combined effects of X explanatory variables that promote or prevent farmers "decision to adopt modern agricultural production technologies". In other words, the model $\ln\left(\frac{P}{1-P}\right)$ in the formula represents log-odds in favor of farm household's decision to adopt modern agricultural production technologies or not to adopt. It is the logarithm of the ratio of probability of adopting the technologies (p) to probability of not adopting them (1-p). The ratio $\left(\frac{P}{1-P}\right)$ shows the odds ratio of probability of adopting the technology to not adopting it. That means it is the ratio of probability of adopting the technology (p) to not adopting the technologies (1-p) in the observational studies. Table 2 presents the variables selected for the descriptive analysis and the binary logistic analysis.

Table 2. Variables selected for the descriptive analysis and the binary logistic analysis

Acronym	Description	Type of measure	Expected sign
Dependent variable			
ADOP	Whether a farmer has adopted or not	Dummy (1 if yes, 0 if no)	
Explanatory variables			
Characteristics of farmer			
AGE	Household head's age	Years	-/+
EDUC	Education of the household head	Years	+
SEX	Male household head	Dummy (1 if yes, 0 if no)	
HS	Household size	Persons	-/+
FS	Farm size	Hectares	-/+
HS	Herd size	Heads	+
OFARM	Off-farm income	Dummy (1 if yes, 0 if no)	+
FPA	Farm productive assets	Tunisian National Dinars	+
HASS	House assets	TND	+
HAI	Have an assets income	Dummy (1 if yes, 0 if no)	+
OWNP	Own pickup	Dummy (1 if yes, 0 if no)	+
OWNM	Own motorbike	Dummy (1 if yes, 0 if no)	+

Innovation characteristics (Kounouz variety)			
HIB	Have innovation benefits	Dummy (1 if yes, 0 if no)	+
HGA	Have good access	Dummy (1 if yes, 0 if no)	+
HLKN	High level of knowledge needed	Dummy (1 if yes, 0 if no)	-
HACN	High adoption cost needed	Dummy (1 if yes, 0 if no)	-
HILN	High intensity labor needed	Dummy (1 if yes, 0 if no)	-
HACS	High adapt capacity in terms of skills	Dummy (1 if yes, 0 if no)	+
HACPI	High adapt capacity in terms of payment of inputs	Dummy (1 if yes, 0 if no)	+
HACAI	High adapt capacity in terms of availability of inputs	Dummy (1 if yes, 0 if no)	+
Innovation characteristics (Feed blocks)			
HIB	Have innovation benefits	Dummy (1 if yes, 0 if no)	+
HGA	Have good access	Dummy (1 if yes, 0 if no)	+
HLKN	High level of knowledge needed for feed blocks	Dummy (1 if yes, 0 if no)	-
HACN	High adoption cost needed for feed blocks	Dummy (1 if yes, 0 if no)	-
HILN	High intensity labor needed for feed blocks	Dummy (1 if yes, 0 if no)	-
HACS	High adapt capacity in terms of skills	(scale 0 to 10)	+
HACPI	High adapt capacity in terms of payment of inputs	(scale 0 to 10)	+
HACAI	High adapt capacity in terms of availability of inputs	(scale 0 to 10)	+
External environment Characteristics			
HDEE	High dependence on external environment	Dummy (1 if yes, 0 if no)	+
DI	Drought intensity	(scale 0 to 5)	+
IIIP	Intensity of increase of input prices	(scale 0 to 5)	+
IIFP	Intensity of increase of food prices	(scale 0 to 5)	+
DMM	Distance to main market	Km	-
DEO	Distance to extension office	Km	-
SF	Soil fertility	Dummy (1 if yes, 0 if no)	-/+
Communication and extension			
EOMSI	Extension office as a main source of information	Dummy (1 if yes, 0 if no)	+
RATPN	Requesting advice for a technical problem from a neighbor	Dummy (1 if yes, 0 if no)	+

Source: Own elaboration from end-line survey data (2019).

4. RESULTS AND DISCUSSION

In this section, the results and discussion will be presented separately for Kounouz and feed blocks.

4.1. Factors Influencing the Adoption of Kounouz

4.1.1. Adoption rate of Kounouz in 2017 and 2018

The results displayed in Table 3 show the number of households that adopted Kounouz in 2017 and 2018 for both the full sample and by treatment groups. In 2018 and for the full sample, a fifth of the households (20.57 percent) adopted Kounouz versus 13.87 percent of households in treatment group 2; 22.63 percent in treatment group 1; 23.43 percent in treatment group 4; and 33.58 percent in treatment group 3.

The number of farmers who are adopters of Kounouz decreased by almost 53 between the cropping seasons 2017/2018 and 2018/2019. In fact, according to the results of the follow-up survey conducted in December 2018, the main reasons of Kounouz non-use are the following:

- The preference of other barley varieties (30.8 percent)
- The unavailability of the variety seeds (19.5
- percent)
- The farmer not planting barley (15.4 percent)
- The price is considered too high (7.2 percent)

Almost 20 percent of the project's farmers have other reasons for not cultivating Kounouz. In this context, focus group discussions conducted with a sample of project farmers in March 2019 revealed the following main reasons for low adoption of Kounouz in the cropping season for low adoption of Kounouz in the cropping season 2018/2019 compared to 2017/2018:

- The unfavorable agricultural season in the year 2017/2018 (high importance)
- The majority of farmers are smallscale and poor
- Most farmers do not grow barley
- Most farmers prefer growing local seeds (seeds purchased on credit and transporting the barley seeds cost-free)
- The price increase of the seeds from 40 to 60 TND (100 kilograms)
- Some farmers re-used Kounouz seeds harvested during the 2017/2018 growing season
- Some farmers prefer growing local seeds rather than buying a low dose of Kounouz (100-200 kilograms)
- The farmers attachment to their traditional agricultural practices

The participation rate of the project farmers in different trainings has a direct influence on the adoption rate of Kounouz in so far as this rate reflects the degree of involvement of the project beneficiaries. Treatment group 3 for the head of the households, and treatment group 4 for women registered the highest rates of training participation (40.85 percent and 41.4 percent respectively). The assessment of the impact of introduced trainings, technical training and female empowerment have a greater influence on the adoption of Kounouz by project farmers than the organizational training. Moreover, some farmers are demotivated by the lack of financial and institutional support for the creation of an association or to imprint a credit following the completion of the organizational training.

Table 3. Frequency of household adoption of Kounouz by treatment groups (T).

Adoption of Kounouz	Control Group		T1		T2		T3		T4		Total	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
No adoption	124	119	73	106	71	118	54	91	86	99	408	533
Adoption	16	10	67	31	69	19	86	46	54	32	292	138
Total	140	129	140	137	140	137	140	137	140	131	700	671
Decreased rate of Kounouz between 2017 and 2018, %	37.5%		53.73%		76.81%		46.51%		40.74%		52.73%	
Participation rate of HH to training %	-		33.04%		36.75%		40.85%		25.57%		36.01%	
Participation rate of women to training %	-		-		-		36.6%		41.4%		39.0%	

Source: Author's elaboration from project data (2019).

4.1.2. Findings from Qualitative Analysis: Descriptive examination

In order to select the relevant variables influencing the adoption of Kounouz, a descriptive analysis was conducted according to the treatment groups (Table 4).

Treatment group 1

Within treatment group 1, compared to non-adopters, the adopters of Kounouz are: more educated, with 5.26 years of education versus 4.88 years on average; have more assets income (9.7 percent versus 3.8 percent on average); and own more land, herd, pickups and motorbikes. For the category of innovation characteristics, 96.2 percent of Kounouz adopters think that the variety has benefits versus 80.6 percent of non-adopters. On average, adopters also have a higher adapting capacity in terms of skills needed (46.4 percent versus 35.4 percent), payments of inputs (39.3 percent versus 13.4 percent) and availability of inputs (21.4 percent versus 7.3 percent) than non-adopters.

Concerning the external environment characteristics, those who adopt Kounouz have less dependence on the external environment (59.3 percent versus 65.0 percent) and a short distance to the market and extension office compared to non-adopters. The analysis of the impact perceived from communication and extension showed that on average 84.0 percent of adopters consider extension offices as a main source of information versus 74.4 percent of non-adopters, and 32.1 percent of adopters request advice for a technical problem from their neighbor compared to 25.0 percent of non-adopters.

Treatment group 2
Within treatment group 2 and in the category of farmer characteristics, the results show that on average adopters of Kounouz are older than non-adopters (62.02 years old versus 56.52 years old). A greater percentage of adopters also have assets income (5.3 percent versus 0.8 percent) and own a pickup and motorbike (21.1 percent and 36.8 percent, compared to 14.4 percent and 25.6 percent respectively) than non-adopters.

For the category of innovation characteristics, on average 91.7 percent of adopters perceive Kounouz to be beneficial compared to 79.5 percent of non-adopters. Only 14.3 percent and 21.4 percent of adopters think that the technology needs a high level of knowledge and high intensity labor respectively, in comparison to 55.4 percent and 53.8 percent respectively of non-adopters. In addition, 21.4 percent of Kounouz adopters have a high adapt capacity in terms of payments of inputs and availability of inputs compared to 12.9 percent and 13.9 percent respectively for non-adopters on average.

Concerning the external environment characteristics, those who adopt Kounouz have more dependence on the external environment than those who do not adopt (64.3 percent versus 53.1 percent on average). With respect to communication and extension, 64.3 percent of adopters consider extension offices as a main source of information, compared to 70.3 percent for non-adopters on average.

Treatment group 3
For the treatment group 3, which registered a higher adoption rate of Kounouz compared to the other groups, the adopters own more herd (30 heads versus 24.2), farm productive assets (5458.70 TND versus 3732.72 TND), house assets (1573.80 TND versus 1011.93 TND), and pickup (26.1 percent versus 14.4 percent) on average than non-adopters. Regarding the innovation characteristics, the majority of the adopters of Kounouz think that the variety has benefits (95.0 percent versus 89.4 percent for non-adopters on average) and have a high adapt capacity in terms of skills needed, payments of inputs, and availability of inputs than non-adopters (46.7 percent, 44.4 percent and 33.3 percent, compared to 39.5 percent, 9.2 percent and 22.4 percent respectively on average).

Concerning the external environment characteristics, those who adopt Kounouz have less dependence on the external environment (44.2 percent versus 52.7 percent on average) and less soil fertility (85.4 percent versus 70.6 percent on average) than non-adopters. With respect to the communication and extension component, 78.3 percent of adopters consider extension offices as a main source of information compared to 74.6 percent of non-adopters on average. They also request advice for a technical problem from their neighbor more than non-adopters (21.6 percent compared to 18.2 percent on average).

Treatment group 4
For treatment group 4, the adopters of Kounouz have a smaller farm size (4.95 hectares compared to 7.12 hectares on average), own less herd (23.43 heads versus 30.46 heads on average) and more often own a pickup (21.9 percent versus 14.1 percent on average) compared to non-adopters. Concerning innovation characteristics, those who adopt the variety have good access, need a high level of knowledge and have a high adapt capacity in terms of skills needed and especially for the payment and availability of inputs compared to the non-adopters.

Concerning the external environment characteristics, adopters have more dependence on the external environment (72.4 percent versus 61.2 percent on average) and a longer distance to travel to the market and extension office compared to the non-adopters (17.59 kilometers and 17.50 kilometers compared to 13.81 kilometers and 13.81 kilometers respectively on average). Regarding communication and extension, 68.8 percent of those who adopt Kounouz consider extension offices as a main source of information compared to 81.7 percent of non-adopters on average.

Table 4. Descriptive analysis of the variables influencing the adoption of Kounouz.

	Full sample Mean	T1 Mean		T2 Mean		T3 Mean		T4 Mean	
		Non adopters	Adopters	Non adopters	Adopters	Non adopters	Adopters	Non adopters	Adopters
Farmer characteristics									
AGE	56.20	56.10	56.00	56.52	62.05	56.12	57.69	55.48	57.47
SEX	93.6	92.5	93.5	95.3	100	91.1	95.7	94.6	90.6
EDUC	4.306	4.075	5.645	3.373	2.105	4.688	4.772	4.377	4.343
HS	5.21	4.88	5.26	5.21	5.95	4.63	5.78	5.28	5.88
FS	5.68	5.83	6.95	5.04	5.37	5.44	5.03	7.12	4.95
HS	25.31	22.367	25.903	30.724	25.421	24.200	30.021	30.467	23.437
OFARM	49.3	49.1	35.5	52.8	52.6	50.0	52.2	50.0	34.4
FPA	4227.88	3269.62	4142.74	4039.26	3376.42	3732.72	5458.70	7782.01	5934.22
HASS	1196.30	1285.76	1202.98	1174.81	1319.47	1011.93	1573.80	1146.20	1100.81
HAI	4	3.8	9.7	0.8	5.3	3.3	4.3	7.6	9.4
OWNP	15.6	14.2	25.8	11.8	21.1	14.4	26.1	14.1	21.9
OWNM	22.2	22.6	29.0	20.5	36.8	25.6	23.9	29.3	15.6
Innovation characteristics									
HIB	85.3	80.6	96.2	79.5	91.7	89.4	95.0	84.5	86,4
HGA	59.1	51.5	59.3	60.7	38.5	57.4	64.3	61.7	73.1
HLKN	58.9	58.6	57.7	55.4	14.3	62.7	61.9	66.7	74.1
HACN	87.4	85.7	88.9	95.2	92.3	92.5	81.0	79.6	84.0
HILN	49.4	50.0	53.8	52.6	21.4	44.6	41.0	59.6	66.7
HACS	37.3	35.4	46.4	41.6	64.3	39.5	46.7	24.6	27.6
HACPI	17.9	13.4	39.3	12.9	21.4	9.2	44.4	14.5	24.1
HACAI	17.9	7.3	21.4	13.9	21.4	22.4	33.3	15.9	27.6
External environment Characteristics									
HDEE	57.9	65.0	59.3	53.1	64.3	52.7	44.2	61.2	72.4
DI	4.74	4.83	4.81	4.68	4.63	4.78	4.57	4.67	4.69
IIIP	4.39	4.38	4.58	4.23	4.67	4.25	4.45	4.35	4.32
IIFP	4.69	4.71	4.74	4.66	4.68	4.67	4.76	4.65	4.66
DMM	12.359	12.083	8.629	11.160	11.447	12.756	11.261	12.272	17.594
DEO	14.522	18.773	12.532	13.820	13.132	12.694	14.174	13.815	17.500
SF	76.3	76.6	79.3	67.5	70.6	85.4	69.8	81.2	77.4
Communication and extension									
EOMSI	74.4	75.3	84.0	70.3	64.3	74.6	78.3	81.7	68.8
RATPN	20.8	25.0	32.1	20.6	21.4	18.2	21.6	21.2	22.2

Source: Own elaboration from end-line survey data (2019).

4.1.3. Findings from quantitative analysis: Logit model

Analysis of full sample - The coefficients of the binary logistic regression model were estimated using the Maximum Likelihood Method (ML) by SPSS Program. The quality of conciliation was tested using the Hosmer and Lemeshow statistic, which is one of the most reliable tests to reconcile the logistic regression model. The results of the model are given in Table 5. The overall percentage of correct predictions is 76.90 percent. The p-value 0.841 uses the Hosmer and Lemeshow Goodness-of-Fit Test, which is computed from the Chi-square distribution with 8 degrees of freedom (d.f), which confirms that the model's estimates fits the data very well. The column, exp (B), gives the exponential of expected value of β raised to the value of the logistic regression coefficient, which is the predicted change in odds for a unit increase in the corresponding explanatory variable. The logistic regression equation for the full sample is expressed as follows:

ADOPKounouz= -6,801+ 0,029 AGE + 0,088EDUC +0,173HS + 0,911HAI + 1,639HACPI+ 0,504IIFP -0,498DI + 0,377IIIP

The results show that the socio-demographic and economic factors AGE, EDUC, and HS are statistically significant and positively affect the adoption of Kounouz for the full sample. The average age is almost 56 and older farmers are more likely to adopt Kounouz than younger farmers, as are farmers with a high education level and a large household size. In addition, the characteristics of innovation represented by HIB and HACPI have major influence on the adoption of Kounouz. In this sense, the project farmers (mostly poor smallholders) who have a high capacity to pay for inputs and resources registered the highest rate of adoption of the variety. In addition, the majority of farmers adopting Kounouz are convinced of the advantages of the variety. With respect to the characteristics of external environment, DI has a negative influence on adoption while IIIP and IIFP have a positive influence. In times of drought, the lack of rainfall encourages the farmers to use the local seeds rather than the improved variety. This finding is confirmed by the decrease of the adoption rate of Kounouz between 2017 and 2018. On the other hand, the increase of food prices and inputs motivates project beneficiaries to adopt the improved variety in order to enhance crop yield and related benefits.

Table 5. Parameter estimates of the binary logistic regression model for factors influencing adoption of Kounouz (full sample)

Variable	B	S.E.	Wald	Sig.	Exp(β)
AGE**	0.029	0.013	4.695	0.030	1.029
EDUC**	0.088	0.037	5.722	0.017	1.092
HS**	0.173	0.070	6.107	0.013	1.188
HIB*	0.911	0.519	3.079	0.079	2.487
HACPI***	1.639	0.333	24.170	0.000	5.148
DI*	-0.498	0.280	3.154	0.076	0.608
IIIP**	0.377	0.181	4.352	0.037	1.457
IIFP	0.504	0.257	3.862	0.049	1.656
Constant**	-6.801	1.957	12.078	0.001	0.001

Notes:

- Test de Hosmer-Lemeshow: Chi-square, 4.171; df.,8; Sig., 0.841; -2 Log likelihood.,313,571a; Cox & Snell R Square, 0.167; Nagelkerke R Square, 0.2.
- *Significance at 10%. **Significance at 5%; *** Significance at 1%.

Source: Own elaboration from model results (2019).

Analysis of Treatment group 1 - The results of the model are given in Table 6. The overall percentage of correct predictions is about 80.60 percent. The p-value 0.643 uses the Hosmer and Lemeshow Goodness-of-Fit Test, which is computed from the Chi-square distribution with 8 degrees of freedom (d.f), which confirms that the model's estimates fit the data well. The column, exp (B), gives the exponential of expected value of β raised to the value of the logistic regression coefficient, which is the predicted change in odds for a unit increase in the corresponding explanatory variable. The logistic regression equation for the treatment group 1 is expressed as follows:

ADOPKounouz = -1,799+ 0,174EDUC + 1,328HACAI+ 1,157HACPI -0,041DEO-0,580OFARM+0,36OWNP + 0,778HAI

The results show that the education of the household head, the high adapt capacity in terms of availability of inputs, and the high adapt capacity in terms of payment of inputs are statistically significant and positively affect the adoption of Kounouz for treatment group 1. Furthermore, the increase in variable HACAI and HACPI by one unit will increase the probability of Kounouz adoption by 3.772 times and 3.181 times respectively. This finding shows the importance of the adapt capacity of households in terms of payment and availability when farmers are deciding whether or not to adopt Kounouz. The distance to the extension office is also statistically significant, but negatively affects adoption. In this sense, the increase in variable DEO by one unit (1 kilometer) will decrease the probability of Kounouz adoption by 0.56 times.

Table 6. Parameter estimates of the binary logistic regression model for factors influencing adoption of Kounouz in treatment group 1

Variable	B	S.E.	Wald	Sig.	Exp(β)
EDUC***	0.174	0.063	7.577	0.006	1.19
HACAI*	1.328	0.78	2.897	0.089	3.772
HACPI*	1.157	0.64	3.271	0.071	3.181
DEO**	-0.041	0.019	4.799	0.028	0.96
OFARM	-0.58	0.546	1.127	0.288	0.56
OWNP	0.36	0.651	0.306	0.58	1.433
HAI	0.778	0.974	0.637	0.425	2.176
Constant***	-1.799	0.57	9.951	0.002	0.165

Notes:

- Test de Hosmer-Lemeshow: Chi-square, 6.036; df.,8; Sig., 0.643; -2 Log likelihood.,95,096a; Cox & Snell R Square, 0.200; Nagelkerke R Square, 0.229.
- *Significance at 10%. **Significance at 5%; *** Significance at 1%.

Source: Own elaboration from model results (2019).

Results from Treatment group 2 - The results of the model are given in Table 7. The overall percentage of correct predictions is 81.80 percent. The p-value 0.777 uses the Hosmer and Lemeshow Goodness-of-Fit Test, which is computed from the Chi-square distribution with 8 degrees of freedom (d.f), which confirms that the model's estimates fits the data well. The logistic regression equation for the treatment group 2 is expressed as follows:

ADOP Kounouz= -4,785 – 1.857 HLKN + 0.033 DMM - 0,213 HILM + 0,054 AGE + 0,835 OWNM + 0,544 HACPI + 0,118 HACAI

The results show that only two variables are statistically significant: AGE positively affects the adoption of Kounouz while the HLKN has a negative effect. Increasing the variable AGE by one unit will increase the probability of Kounouz adoption by 1.053 times. In addition, adopters do not need a high level of knowledge to begin cultivating the variety.

Table 7. Parameter estimates of the binary logistic regression model for factors influencing the adoption of Kounouz in Treatment group 2

Variable	B	S.E.	Wald	Sig.	Exp(β)
HLKN*	-1.857	1.077	2.971	**0.085**	0.156
DMM	0.033	0.037	0.807	0.369	1.034
HILN	-0.213	0.976	0.048	0.827	0.808
AGE**	0.051	0.027	3.632	**0.057**	1.053
OWNM	0.835	0.753	1.232	0.267	2.306
HACPI	0.544	0.830	0.430	0.512	1.723
HACAI	0.118	0.824	0.020	0.886	1.125
Constant**	-4.785	1.925	6.181	0.013	0.008

Notes:

- Test de Hosmer-Lemeshow: Chi-square, 4.818; df., 8; Sig., 0.777; -2 Log likelihood.,63,256a; Cox & Snell R Square, 0.146; Nagelkerke R Square, 0.225; *Significance at 10%.
- **Significance at 5%; *** Significance at 1%.

Source: Own elaboration from model results (2019).

Analysis from Treatment group 3 - The results of the model are given in Table 8. The overall percentage of correct predictions is 75.70 percent. The p-value 0.966 uses the Hosmer and Lemeshow Goodness-of-Fit Test, which is computed from the Chi-square distribution with 8 degrees of freedom (d.f), which confirms that the model's estimates fit the data well. The logistic regression equation for the treatment group 3 is expressed as follows:

ADOP Kounouz= -1,020+0.424OWNP + 2.088HACPI - 1,066SF + 0,001HASS + 0,006DEO

The results show that HACPI and HASS are statistically significant and positively affect the adoption of Kounouz for treatment group 3. Furthermore, an increase in the variables HACPI and HASS by one unit will increase the probability of Kounouz variety adoption by 8.068 times and 1.001 times respectively. This finding shows the importance of the adapt capacity of households in terms of payment in the decision-making process. However, the SF is also statistically significant and negatively affects the adoption of the variety. In this case, an increase in the variable SF by one unit (1 kilometer) will decrease the probability of adoption by 0.366 times.

Table 8. Parameter estimates of the binary logistic regression model for factors influencing the adoption of Kounouz in Treatment group 3.

Variable	B	S.E.	Wald	Sig.	Exp(β)
OWNP	0.429	0.664	0.418	0.518	1.536
HACPI***	2.088	0.581	12.932	0.000	8.068
SF*	-1.006	0.575	3.062	0.080	0.366
HASS*	0.001	0.000	3.028	0.082	1.001
DEO**	0.006	0.014	0.148	0.700	1.006
Constant	-1.020	0.636	2.572	0.109	0.360

Notes:

- Test de Hosmer-Lemeshow: Chi-square, 2.411; df.,8; Sig., 0.966; -2 Log likelihood.,117,390a; Cox & Snell R Square, 0.236; Nagelkerke R Square, 0.321.
- *Significance at 10%. **Significance at 5%; *** Significance at 1%.

Source: Own elaboration from model results (2019).

Results from Treatment group 4 - The results of the model are given in Table 9. The overall percentage of correct predictions is about 72.20 percent. The p-value 0.634 uses the Hosmer and Lemeshow Goodness-of-Fit Test, which is computed from the Chi-square distribution with 8 degrees of freedom (d.f), which confirms that the model's estimates fit the data well. The logistic regression equation for the treatment group 4 is expressed as follows:

ADOPKounouz = -2,729-1.388OFARM + 1.613HLKN+1,460HACPI-1,646HILM + 1,589HDEE + 0.084 DMM

The results show that HLKN, HACPI, HDEE and DMM are statistically significant and positively affect the adoption of Kounouz for treatment group 4. Increasing the variables HLKN, HACPI and HDEE by one unit will increase the probability of adoption by 5.018, 4.307 and 4.897 times respectively. This finding shows the importance of the characteristics of innovation and the external environment when farmers decide whether or not to cultivate the improved variety. Conversely, the OFARM income and the HILN are statistically significant and negatively affect the adoption of Kounouz. Increasing the variables OFARM and HILN by one unit will decrease the probability of adoption by 0.255 and 0.193 times respectively.

Table 9. Parameter estimates of the binary logistic regression model for factors influencing the adoption of Kounouz in Treatment group 4

Variables	B	S.E.	Wald	Sig.	Exp(β)
OFARM**	-1.388	0.588	5.575	0.018	0.250
HLKN*	1.613	0.833	3.751	0.053	5.018
HACPI**	1.460	0.717	4.151	0.042	4.307
HILN*	-1.646	0.849	3.756	0.053	0.193
HDEE**	1.589	0.644	6.088	0.014	4.897
DMM**	0.084	0.036	5.561	0.018	1.088
Constant**	-2.729	0.943	8.379	0.004	0.065

Notes:

- Test de Hosmer-Lemeshow: Chi-square, 6.116; df.,8; Sig., 0.634; -2 Log likelihood.,83,320a; Cox & Snell R Square, 0.205; Nagelkerke R Square, 0.284.
- *Significance at 10%. **Significance at 5%; *** Significance at 1%.

Source: Own elaboration from model results (2019).

Figures 3 and 4 show a summary of factors that influence adoption for the full sample and by treatment groups. The analysis confirms that both extrinsic variables, such as the characteristics of the farmer, the characteristics of the innovation and the external environment, as well as intrinsic variables, such as knowledge, perceptions, and attitudes, influence the decision to begin farming the improved variety. We notice that the innovation characteristics are the main influence in the decision-making process.

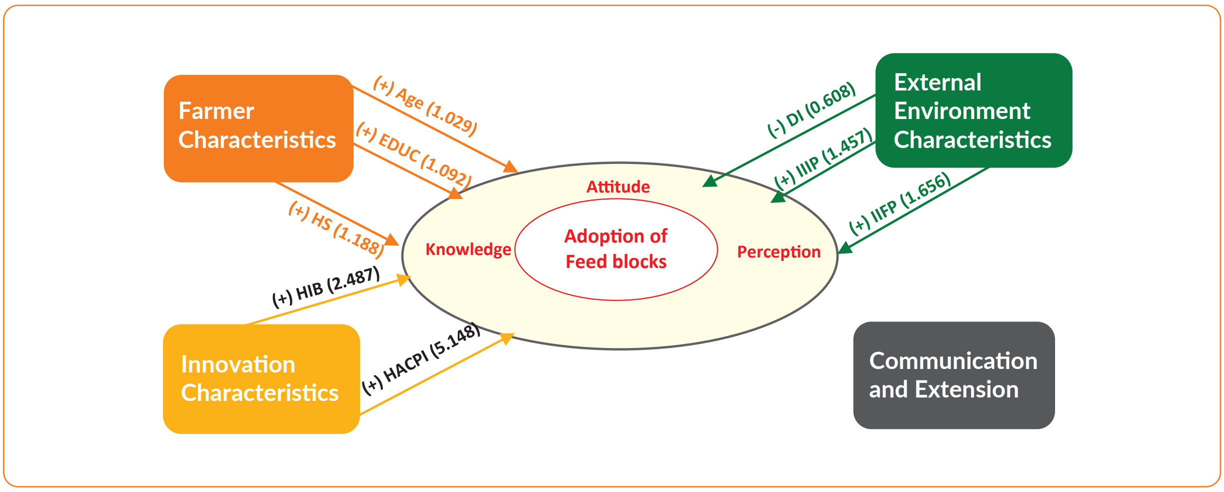

Figure 3. Factors influencing the adoption of Kounouz in 2018.
Source: Author's elaboration from model results (2019).

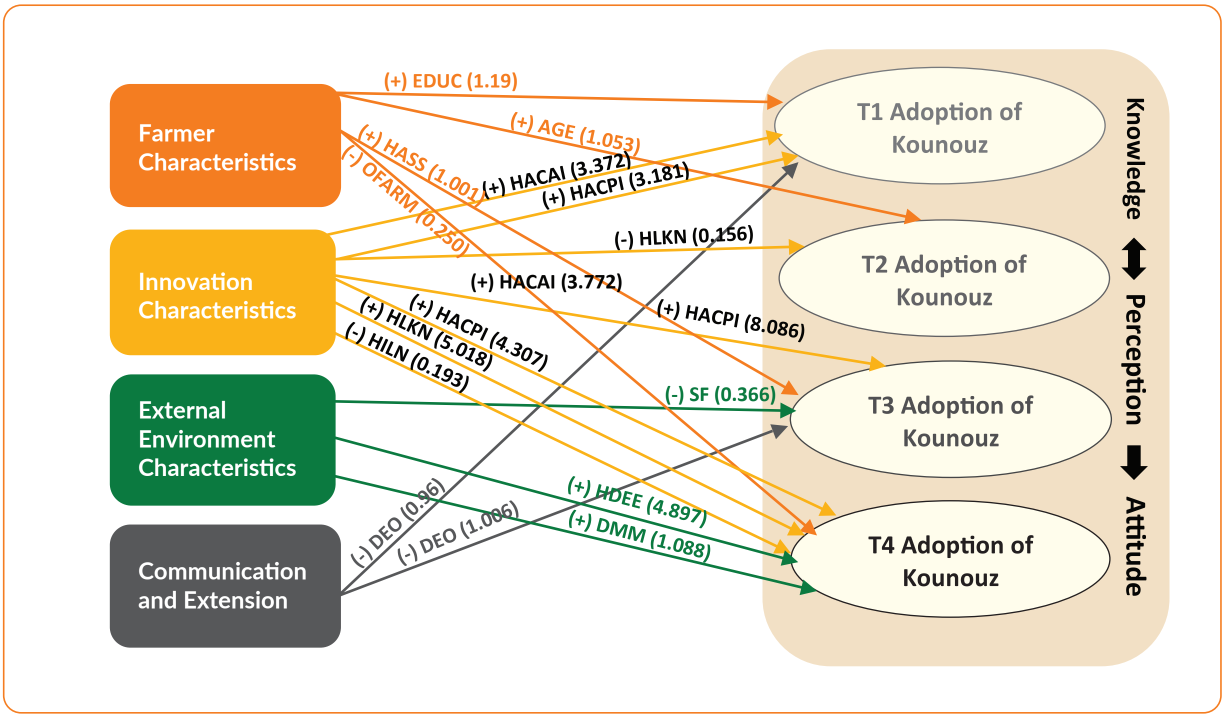

Figure 4. Factors influencing the adoption of Kounouz in 2018 by treatment groups
Source: Author's elaboration from model results (2019).

4.2. Factors Influencing the Adoption of Feed Blocks Technology

Results displayed in Table 10 shows the frequency of households adopting feed blocks in 2018 by treatment groups. For the full sample, only 2.24 percent of the households adopted feed blocks compared to 1.53 percent for T4, 2.17 percent for T2, 2.92 percent for T3 and 4.38 percent for T1. This finding indicates that the adoption of feed blocks is very low for all treatment groups.

Table 10. Frequency of feed blocks adopters by treatment groups

Adoption of feed blocks	Control Group	T1	T2	T3	T4	Total
No adoption	129	131	134	133	129	656
Adoption	0	6	3	4	2	15
Total	129	137	137	137	131	671

Source: Own elaboration from analysis of project data (2019).

4.2.1. Results from qualitative analysis: Descriptive analysis

With the aim to identify the relevant variables influencing the adoption of feed blocks, a descriptive analysis was conducted on the full sample (Table 11).

A fifth of those who began using feed blocks are female. Adopters typically own more herd (37.80 heads versus 25.32 on average) and own a motorbike (46.70 percent versus 21.60 percent on average) compared to non-adopters. Regarding the innovation characteristics, on average almost the two thirds of the adopters of feed blocks think that the technology has benefits, compared to 36.05 percent of non-adopters, and 53.85 percent of adopters have good access to feed blocks compared to 30.00 percent of non-adopters Furthermore, in comparison to non-adopters, those who adopt feed blocks have a smaller percentage of households that declare the technology needs a high level of knowledge (25.00 percent versus 49.3 percent) and a high adoption cost (60.00 percent versus 86.30 percent). In addition, the adopters have a higher adapt capacity in terms of skills needed, of payments of inputs and availability of inputs than non-adopters (6.08 percent, 4.69 percent and 4.85 percent, compared to 3.91 percent, 3.59 percent and 3.16 percent respectively).Concerning the external environment characteristics, adopters have greater dependence on the external environment (61.5 percent compared to 39.60 percent) and a longer distance to the market and extension office (15.53 kilometers and 16.26 kilometers compared to 12.28 kilometers and 14.48 kilometers respectively on average) and less soil fertility (60.0 percent against 76.7 percent on average) compared to non-adopters. In the category of communication and extension, 60.0% percent of those who adopted feed blocks consider the extension office as a main source of information, compared to 74.7 percent of non-adopters.

Table 11. Descriptive analysis of the variables influencing the adoption of feed blocks

Variables	Adopters of feed blocks Means	Non-adopters of feed blocks Means
	Farmer characteristics	
AGE	56.00	56.20
SEX	80.0	90.9
EDUC	4.26	4.30
HS	4.27	5.22
FS	5.38	5.69
HS	37.80	25.32
OFARM	33.33	50.23
FPA	5088.67	4208.20
HASS	1021.73	1200.29
HAI	0.00	4.10
OWNP	13.30	15.70
OWNM	46.70	21.60
	Innovation characteristics	
HIB	66.66	36.05
HGA	53.85	30.00
HLKN	25.00	49.30
HACN	60.00	86.30
HILN	40.00	44.60
HACS	6.08	3.91
HACPI	4.69	3.59
HACAI	4.85	3.16
HIB	61.50	39.60
	External environment Characteristics	
DI	4.87	4.73
IIIP	4.14	4.39
IIFP	4.67	4.69
DMM	15.573	12.282
DEO	16.267	14.482
SF	60.00	76.70
	Communication and extension	
EOMSI	63.60	74.70
RATPN	21.40	20.70

Source: Author's elaboration from model results (2019).

4.2.2. Findings from quantitative analysis: Logit model

The results of the model are given in Table 12. The overall percentage of correct predictions is 93.60 percent. The p-value 0.903 uses the Hosmer and Lemeshow Goodness-of-Fit Test, which is computed from the Chi-square distribution with 8 degrees of freedom (d.f), which confirms that the model's estimates fit the data well. The logistic regression equation for the full sample is expressed as follows:

ADOPFeedBlocks = -2,295 – 1.139OFARM + 2.674OWNM – 1,458SF + 1,618HIB-2,213HLKN + 1,317HDEE –2,092SEX+ 0,052 DMM

The results show that OWNM, HIB, HDEE and DMM are statistically significant and positively affect the adoption of feed blocks. Moreover, the increase in variable OWNM by one unit will increase the probability of feed block adoption by 14.494 times. This finding demonstrates the importance for farmers of possessing a means of transport when deciding whether or not to adopt the technology. In addition, the increase in variable HDEE by one unit will increase the probability of feed block adoption by 5.043 times.

The high dependence on the external environment spurs the project households to adopt feed blocks. An increase in the variable DMM by one unit will increase the probability of feed blocks adoption by 1.054 times. This finding can be explained by the fact that the adopters of feed blocks who are located far from the main market generally have a means of transport and consequently have good access to the technology. However, the OFARM, SF, HLKN and SEX are statistically significant and negatively affect adoption. In this sense, the increase in variable SEX by one unit will decrease the probability of feed blocks adopting by 0.123 times, meaning that female-headed households are more motivated to adopt the technology than male-headed households.

Table 12. Parameter estimates of the binary logistic regression model for factors influencing adoption of feed blocks (full sample)

Variables	B	S.E.	Wald	Sig.	Exp(β)
OFARM	-1.139	0.869	1.719	0.190	0.320
OWNM* **	2.674	0.906	8.719	0.003	14.494
SF*	-1.458	0.828	3.098	0.078	0.233
HIB*	1.618	0.828	3.817	0.051	5.043
HLKN**	-2.213	0.969	5.212	0.022	0.109
HDEE*	1.317	0.765	2.966	0.085	3.733
SEX*	-2.092	1.149	3.314	0.069	0.123
DMM	0.052	0.046	1.313	0.252	1.054
Constant*	-2.295	1.263	3.304	0.069	0.101

Notes:

- Test de Hosmer-Lemeshow: Chi-square, 3.451; df., 8; Sig., 0.903; -2 Log likelihood.,56,760a; Cox & Snell R Square, 0.135; Nagelkerke R Square, 0.359.
- *Significance at 10%. **Significance at 5%; *** Significance at 1%.

Source: Author's elaboration from model results (2019).

The results displayed in Figure 5 show a summary of factor dimensions influencing the adoption of feed blocks. Of note is that the communication and extension element does not influence the decision-making process for the adoption of the technology, and farmer characteristics are the main influence for adoption through the OWNM variable (Exp(β)=14.494).

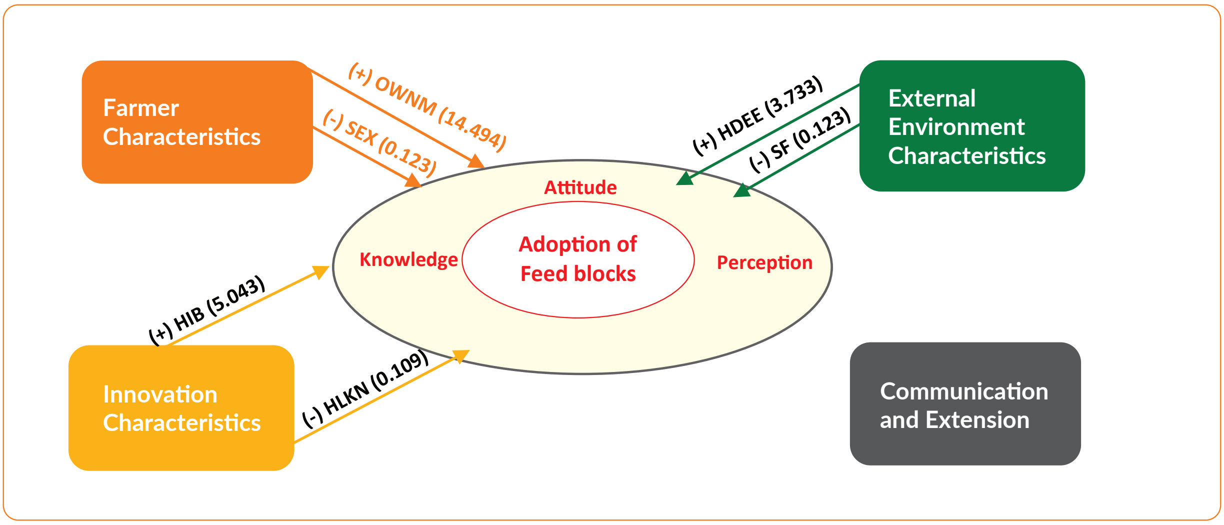

Figure 5. Factors influencing the adoption of feed blocks technology in 2018
Source: Author's elaboration from model results (2019).

5. CONCLUDING REMARKS AND POLICY IMPLICATIONS

This study provides an analytical framework for examining the adoption process of agricultural innovations that simultaneously takes into account the interaction between the characteristics of the farmers, the innovations and external environment and the influence of communication and extension variables in the decision-making process of the adoption of Kounouz and feed blocks in 2018.

The knowledge, attitudes, and perceptions of these technologies play a key role in the decision to adopt. In this sense, the innovation characteristics like the benefits perceived, the knowledge needed, the payment and availability of inputs and resources have a major influence on the adoption of Kounouz and feed blocks for smallholder farmers. The conventional studied variables such as the farmer characteristics (age, education level, household assets, and off-farm income for Kounouz; and sex and owning a motorbike for feed blocks) are important and affect the adoption indirectly by influencing the knowledge, attitudes, and perceptions, which in turn influence the farmers' decisions of whether or not to adopt these technologies.

The characteristics of the external environment affect the development of knowledge, attitudes, and perceptions especially through the degree of dependence of the farmers to the shocks perceived. Autonomous farmer's adaptation was insufficient to adequately address the threats posed by climate change. Interventions could include programs (drought preparedness plans, soil erosion and water harvesting plans, etc.) that target the farmers' knowledge of how to face climate change difficulties in the best possible ways.

The role of extension and training is crucial in the development of knowledge, perceptions, and attitudes about agricultural innovations. In the case of Kounouz, the distance to the extension office negatively affects the adoption of this technology. The lack of communication between farmers and extension agents mostly reduce their knowledge, attitudes, and perceptions of the innovative technologies. Further to this, a reflection should be done about how extension agents can go from simple technical providers to a catalyst of technologies adoption.

To improve the adoption of Kounouz and feed blocks in the study area, government actors should understand what knowledge and attitudes farmers have in relation to these technologies and how these are brought to them. This information can be used to redesign policies, technologies, and extension activities to be more appropriate for farmers' preferences and specific conditions, leading to greater adoption and lasting impact.

As the adoption process is very complex, it is almost impossible to understand the influence of all possible factors involved as well as their interdependencies. The analytical framework presented in this study attempts to bring together all variables which play a role in the decision-making process; however, more information is needed on how the extrinsic variables are related to each other and how they shape the intrinsic variables (Meijer et al. 2014). Otherwise, a potential line of research is the extension of the applied framework to other geographical contexts and to time spans that allow the monitoring of farmers' perspectives.

6. REFERENCES

Ajzen I. 1991. The theory of planned behavior. Organizational behavior and human decision processes, 50 (2), 179–211. Ajzen, I., 2011. The theory of planned behaviour: reactions and reflections. Psychology & health, 26 (9), 1113–1127.

Aldrich J.H. and Nelson D.F. 1984. Linear Probability, Logit and Probit Models. Sage Publications, London, 95 pages.

Akroush, S., Dhehibi, B., Dessalegn, B., Hadidi, M.T.T., Abo-Roman, M. (2017). Factors Affecting the Adoption of Water Harvesting Technologies: A Case Study of Jordanian Arid Area Sustainable Agriculture Research. Vol 6, pp. 80-89. ISSN 1927-050X.

Ben Salem H., Zaibet L. and Ben-Hammouda M., 2006. Perspectives de l'adoption du semis direct en Tunisie. Une approche économique. In : Arrue Ugarte J.L. (ed.), Cantero-Martínez C. (ed.). Troisièmes rencontres méditerranéennes du semis direct. Zaragoza : CIHEAM, 69-75 (Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 69).

Binswanger H.P., 1980. Attitudes Toward Risk, Experimental Measurement in Rural India. [ejournal] 3 (62). Available through Uppsala University library website http://www.jstor.org.ezproxy.its.uu.se/stable/pdf/1240194.pdf?refreqid=excelsior%3A5ea4fa0901da5a dc3e514a3416f3fc07.

Bradford L.E. 2009. A Complicated Chain of Circumstances: Decision Making in the New Zealand Wool Supply Chains. [online] Available through http://researcharchive.lincoln.ac.nz/bitstream/handle/10182/2156/bradford_phd.pdf?sequence=1&isAll owed=y

Dhehibi B., Zucca C., Frija A. and Kassam S.N. 2018. Biophysical and econometric analysis of adoption of soil and water conservation techniques in the semiarid region of sidi bouzid (Central Tunisia). New Medit, N.2, pp 15-28.

Dhraief MZ., Bedhiaf S., Dhehibi B., Oueslati-Zlaouia M., Ouessama J. and Salah Ben-Youssef. 2019. Factors affecting innovative technologies adoption by livestock holdersin arid area of Tunisia. New Medit, in press.

Fishbein M. and Ajzen I. 1975. Belief, attitude, intention, and behavior: an introduction to theory and research. Reading, MA: Addison-Wesley.

Fouzai, A., Smaoui M., Frija A. and Dhehibi, B. 2018. Adoption of Conservation Agriculture Technologies by Smallholder Farmers in the semiarid region of Tunisia: Resource constraints and partial adoption. Journal of New Sciences, vol 6 (1), pp. 105-114.

Gould P.R. 1963. Man against his environment; a game-theoretic framework. [online] Available at: https://www.calpoly.edu/~aamendes/GTweb/GhanaFarmers.pdf Howes R. 1967. A test of a line as programming model for agriculture. Papers of the Regional Science Association, 19, pp. 123-40.

INS. National Institute of Statistics, Statistical yearbook of Tunisia, 2016. (in Arabic)

Klein G.A., Orasanu J., Calderwood R. and Zsambok, C.E., 1993. Decision Making in Action: Models and Methods. Ablex, Norwood. [online] Available at: https://ac-els-cdncom.ezproxy.its.uu.se/0001691894900396/1-s2.0-0001691894900396-main.pdf?_tid=3003817 0-43aa46f6-b339-55b9ae8a4136&acdnat=1526662015_28a6db7b02ce96a0a2470ecfb3ee4313

Meijer SS., Catacutan D., Ajayi O.C., Sileshi G.W. and Nieuwenhuis M. 2015. The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa, International Journal of Agricultural Sustainability, 13:1, 40-54.

Ng'ombe J., Kalinda T., Tembo G. and Elias Kuntashula. 2014. Econometric Analysis of the Factors that Affect Adoption of Conservation Farming Practices by Smallholder Farmers in Zambia. Journal of Sustainable Development. Vol 7, pp. 124-138. ISSN 1913-9063.

Noltze M., Schwarze S. and Qaim, M. 2012: Understanding the adoption of system technologies in smallholder agriculture: the system of rice intensification (SRI) in Timor Leste. Agricultural Systems 108, 64-73.

Rogers C.R. (1961). On becoming a person. Oxford, England: Houghton Mifflin.

Rogers E.M. 1995. Diffusion of Innovations. New York: Simon & Schuster.

Rogers E.M. 2003. Diffusion of Innovations, New York: Free Press. 551 pages.

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