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Factors Affecting the Adoption of Innovative Technologies by Livestock Farmers in Arid Area of Tunisia

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Abstract

Despite the efforts to promote adoption of innovative technologies (IT) by the Government and international development projects, the adoption rate among farmers has always been low in Tunisia. This paper aims to investigate the determinants of farmer's decisions to adopt IT in the arid area of Tunisia. Economic, socio-demographic and institutional variables were selected as factors. A sample of 200 farmers was considered; only half of them adopted the IT. A binary logistic regression was used for the analysis. Regarding economic and socio-demographic factors, farm education, size of cattle flocks and off-farm income were statistically significant and positive influence on technology adoption while age and farm experience had significant and negative effects on IT adoption decision. To enhance the adoption ofIT, Government should firstly focus on educating young farmers with large cattle flock size and non-farm income. For the institutional factors, member of association, extension services and source of technology knowledge were significant factors and affected positively the adoption decision. In contrast, it was found that labor and credit services do not significantly influence adoption of IT. Based on these results, Government should intensify training programs for farmers and for extension agents with the collaboration of the project manager. Decision makers should consider this research for better targeting farmers and a better adoption and diffusion of IT in Tunisia. This understanding could provide important clues for research and policy makers to devise better strategies for the IT adoption, while helping rural farmers targeting their opportunities for a better income.

Keywords

Adoption Decisions, Innovative Technologies, Livestock Arid Areas, Logit, Tunisia.

1. Introduction

Agriculture contributes by 14% in the GDP, 10% of the total export incomes and by 20% for the employment of the active population. Livestock as a main agricultural activity represented 4% of the country's GDP and contributed by 41% of total agriculture production (17% red meat, 10% milk, 8% poultry meat, 4% eggs and 1.8% others) including 759 000 cows, 7 million sheep, 1.5 million goats and 70 000 dromedary females (INS, 2015). The livestock sector is rising steadily since 1990 (4.1% average annual growth). This strong increase is due to the combined increase in poultry production and dairy production, which evenly divided represent over half the segment value. The livestock sector, which is heavily supported by the government (animal health costs carried by the state, national milk collection and production plants, etc.) almost satisfies the total domestic demand and even exports to neighboring countries.

The target region, Sidi-Bouzid, is characterized by a large and rapidly increasing food deficits, highly variable income levels, and limited natural resources, particularly arable land and water. Inhabitants are the poorest, the most socially disadvantaged, the most scattered and disfavored in terms of infrastructural and institutional support. A large number of the small farmers in the region are deriving most of their family income from barley/livestock based systems particularly because of the flexibility of barley could offer both as feed and/or food crop, and because sheep herding is quite profitable in the region. The strategy followed by Mashreq and Maghreb (M&M) project is to reduce the cost of production by reducing the concentrates used in the animal feed, and by relying more on on-farm feed production and other alternative feed sources that are cheap and locally available. Research conducted within M&M project showed the important role of barley (grain and straw) and cactus importance in the feeding calendar all year around (Haddad et al., 2007). New barley cultivars were selected by farmers and grown in demonstration fields. The cultivars included 'Rihane' and local accessions like "Ardhaoui" and "Souihli". Also, direct grazing of dual purpose barley and vetches is one aspect of crop/livestock integration. Improving the nutrition of small ruminants by using alternative feed sources and feed supplements was an important objective in Phase II. This includes feed blocks, urea as a source of nitrogen supplement and to upgrade straw quality (Nefzaouiet al., 2008, 2011a). Moreover, spineless cactus has been introduced in the target site and has been used as animal feed to fill the gap during drought years and dry seasons (Haddad, 2007, Nefzaoui, 2011b). To help communities to produce their feed blocks, an improved machine has been locally designed and manufactured to process feed blocks. Using locally available by-products, different formulas have been developed and tested by farmers; the global assessment is that the use of feed blocks resulted in increasing sheep production efficiency by 32% (Nefzaoui et al., 2008). Cactus is a good and cheap source of energy; it is an excellent supplement to poor roughages like straw. Cactus is well adapted to harsh environment and has a high biomass yielding (200 to 100 tons of pads under a rainfall of 200 to 350 mm without any input). A combined diet including barley straw, cactus and Atriplex is able to maintain sheep and ensure a moderate production during the frequent drought years. The M&M project has developed a genetic improvement strategy to improve small ruminant productivity at the community level. Improved rams were introduced in order to reverse inbreeding effects and low growth rates. The introduction of improved rams increased the average daily gains by an amount of 1 to 4.5 kg at 90 days (Bedhiafet al., 2005). The number of farmers willing to use improved rams is increasing.

The rapid development of the livestock sector may be attributed to technological innovations. Much of the livestock innovation is coming from developed countries and some of these are difficult to apply in developing countries as Tunisia. According to Mwangi and Kariuki (2015), the rate of adoption of these technologies has remained low in most of the developing countries. In Tunisia, the majority of smallholder farmers rely on traditional methods of production and this has lowered the level of productivity. According to Elloumi et al. (2005), adoption rate of feed blocks at national level (Tunisia) was up to 5.17% during 1999-2000 cropping season. In addition, despite the good performance of feed blocks technology, the main constraints remain the development of semi-mechanized feed block manufacturing at the community level. The introduction of new technologies often leads to some change in the functioning of the production unit. These changes in turn have impact on the whole household-farm system.

The demand of livestock products increased between 2005 and 2015 by 21% for red meat and poultry and by 38% for dairy products (INS, 2015). Increasing agricultural productivity is critical to meet expected rising demand and, as such, it is instructive to examine recent performance in cases of modern agricultural technologies. The major challenge for policy makers to increase productivity in the livestock sector is to improve the adoption rate of innovative technologies to farmers. In Sidi-Bouzid governorate, a set of innovative technologies was introduced in the last two decades in the livestock sector through international development projects or national institution. The main innovative technologies adopted by farmers in the livestock sector are the feed blocks, improved barley varieties, cactus chopper, improved rams, automatic waterer and solar milk cooling system.

The objectives of this study twofold (i) First to assess farmer's perceptions of IT and secondly (ii) to determine the major factors influencing farmer's adoption decisions. This study offers for policy makers important considerations that could stimulate and sustain adoption of these IT in Tunisian arid agricultural areas. The present study is based on the hypothesis that the farm adoption decision of farmers has no relationship with the type of technology.

2. Review of the Literature: Technology Adoption

Several empirical studies have been carried out to investigate the factors that determine agricultural technology adoption (Katungi and Akankwasa, 2010; Akudugu*et al.,* 2012; Loevinsohn*et al.,* 2012; Adesina and Baidu-Forsen, 1995). The farmers' decisions about whether and how to adopt new technology are conditioned by the dynamic interaction between characteristics of the technology itself and the array of conditions and circumstances (Loevinsohn*et al.,* 2012). Therefore, factors affecting adoption of innovative technologies were classified into different categories: Economic, social and institutional factors according to Akudugu et al., (2012); Social, economic and physical categories for Kebede *et al.,* (1990) as cited by Lavison (2013); Farmer characteristics, farm structure, institutional characteristics and managerial structure according to McNamara *et al.,* (1991); Informational, economic and ecological for Nowak (1987) and human capital, production, policy and natural resource characteristics for Wu and Babcock (1998). Most adoption studies have attempted to measure socio-demographic factors, through the farmer's education, age, experience and household size (Fernandez-Cornejo *et al.,* 2007; Keelan *et al.,* 2009; Mignouna*et al.,* 2011). Education of the farmer has been assumed to have a positive influence on farmers' decision to adopt modern technology. In fact, education level of a farmer increases his ability to obtain; process and use information relevant to the adoption of a new technology (Mignouna*et al.,* 2011; Lavison 2013; Namara*et al.,* 2013). Age is considered as a determinant of adoption of modern technology. According to Mauceri et al., (2005), younger farmers are typically less risk-averse and are more willing to try new technologies than older farmers who have an increase in risk aversion and a decreased interest in long-term investment in the farm. On the contrary, Kariyasa and Dewi (2011) considered that older farmers are assumed to have gained knowledge and experience over time and are better able to evaluate technology information than younger farmers. Household size is especially used to measure labor availability. Mignouna*et al.,* (2011) considered household size as an adoption process in that, a larger household have the capacity to relax the labor constraints required during introduction of modern technology.

Regarding economic factors, farm size is considered as one of the most important determinant of technology adoption. Many studies have reported a positive relation between farm size and adoption of agricultural technology (Uaiene*et al.,* 2009; Mignouna*et al.,* 2011, Lavison 2013). Farmers with large farm size (in terms of land or livestock herd) are likely to adopt new technologies. On the contrary, some studies have shown a negative influence of farm size on the adoption of new agricultural technology (Harper *et al.,* 1990) or have reported insignificant or neutral relationship with adoption (Samiee et al. 2009). Djemali*et al.,* (2009) reported that every large farm, member of the association, was asked to back up a number of small farmers in neighboring area. Small flock holders in the region were encouraged to sell their milk through the Sicilo-Sarde breed association which doubled milk price sale after negotiating it with cheese making industry. Off farm income has been shown to have a positive impact on technology adoption. Reardon *et al.,* (2007) considers off-farm income as an important strategy for rural households to overcome credit constraints in many developing countries. According to Diiro (2013) off- farm income is expected to provide farmers some capital for purchasing productivity enhancing inputs such as improved seed and fertilizers. Some studies on technologies that are labor intensive have shown negative relationship between off-farm income and adoption. The pursuit of off-farm income by farmers may undermine their adoption of modern technology by reducing the amount of household labor allocated to farming enterprises (Goodwin and Mishra, 2004).

Concerning institutional factors, the literature described both the positive and negative impacts of the social network on technology adoption (Katungi and Akankwasa, 2010; Conley and Udry, 2010). Katungi and Akankwasa (2010) found that farmers who participated more in community-based organizations were likely to engage in social learning about the technology hence raising their likelihood to adopt the technologies. The extension service is the key driving factor behind technology development in the agricultural sector in developing countries. In fact, proven agricultural technologies that can improve lives often have low adoption rates. Agriculture extension is a common method to introduce these innovative technologies. According to Mwangi and Kariuki, (2015), availability and access to extension services has also been found to be a key aspect in technology adoption. Many authors have reported a positive relationship between extension services and technology adoption (Mignouna*et al.,* 2011; Akudugu*et al.,* 2012; Mwangi and Kariuki, 2015). Akudugo (2012) has explained that access to extension services can counteract the negative effect of lack of formal education of farmers which hinders technology adoption. In developing countries, extension agents usually select a particular contact farmer who is recognized as the most influential agent to deliver new technology (Genius *et al.,* 2010, Silva and Broekel, 2016). Access to credit is considered as one of the most important determinant of technology adoption. According to Simtowe and Zeller (2006), access to credit promoted the adoption of risky technologies through relaxation of the liquidity constraint as well as through the boosting of household's-risk bearing ability. Acquisition of information about a new technology is another factor that determines adoption of technology. Khalid *et al.,* (2017) indicated that the information obtained directly from the project manager has a positive influence on technology adoption. This is an indication of the importance of obtaining accurate and sufficient information on the nature of the technology and what benefits can be achieved when using it, which is an incentive to encourage farmers to adopt technology. Access to information reduced the uncertainty about a technology's performance hence may change individual's assessment from purely subjective to objective over time (Bonabana- Wabbi, 2002).

3. Methodological Framework

3.1. Study Area

The data was carried out in the governorate of Sidi-Bouzid located in Central Tunisia which is characterized by low levels of economic activity, high incidence of droughts and a high concentration of rural population (75%). It covers an area of 7405 km^2 and it is characterized by an arid climate with an annual rainfall between 200 and 300 mm. It was for many years ago disfavored in terms of infrastructural and institutional support and beside the limited natural resources, particularly arable land and water, a large number of the small farmers are deriving most of their family income from barley/livestock based systems and sheep fattening practice is quite profitable in the region. In fact, the Sidi-Bouzid region produced in 2014 a total of 325,000 lambs and for the Aid el Edha festivity, this governorate contributed by 38% of the total national lamb production (Bedhiaf*et al.,* 2015). According to national statistics, Sidi-Bouzid governorate is ranked number one nationwide in terms of collected cattle milk with a contribution of 293,000 l/day (11 to 15% of the national volume). The dairy cattle population is about 35,000 cows owned in the majority by small producers (≤ 6 cows) with a daily production volume of 20 to 60 liters per farm (INS, 2015).

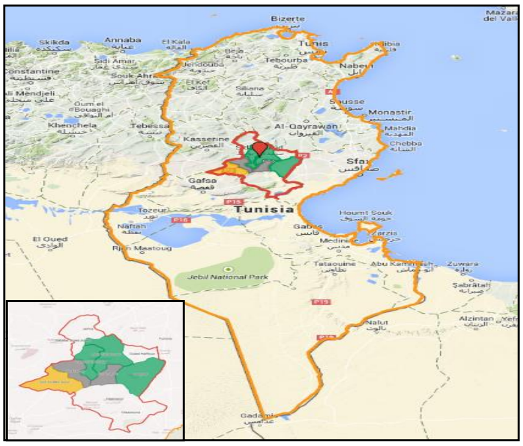

Figure 1. Map of the study site in Tunisia

3.2. Innovative technologies in the livestock sector

In our study, six innovative technologies were selected: feed blocks, cactus chopper, automatic waterer, solar milk cooling system, improved rams and improved barley varieties. These technologies were introduced by different international development projects as the project "Provision of proven feed resource technologies to improve the red meat value chain in Tunisia" in 2015, the project “Field testing of an innovative solar powered milk cooling solution for the higher efficiency of the dairy subsector in Tunisia” in 2015, the CGIAR Research Program (CRP) on " Integrated Agricultural Production Systems for Improved Food Security and Livelihoods in Dry Areas" in 2013, the Mashreq/Maghreb project “The development of integrated crop/livestock production in low rainfall areas of Mashreq and Maghreb regions" in 1995. Other national development projects were established during the last decade with the collaboration of the Livestock and Pasture office, the main actor promoting innovative technologies to farmers.

The introduction of innovative technologies into farmer production system allows numerous benefits. Feed blocks provide flexibility to farmers to choose the ingredients to be included in the feed block and its use as supplements in drought and other harsh conditions. In addition, the blocks can be prepared when the ingredients' cost is low and stored for later use. Cactus is identified as alternative feed resources in summer and autumn to small ruminants in arid and semi-arid regions in Tunisia. The cactus introduced to animals in chopped form. This technology has replaced the old method of cutting cactus pads which is a painful, dangerous and time consuming method. Automatic waterers are standard equipment on most farms because of their convenience and efficiency. They consist of an insulated base and a heated bowl that automatically fills with water from a pressurized line. These “automatic waterers” essentially are appliances hooked into water supply lines that can provide a reliable water source for animals without a daily attention. The solar milk cooling system is an innovative technology to cool milk on the farm, it is entirely based on renewable energy. This facilitates a flexible cooling of the milk on the farm or during transport. Improved rams were introduced in Sidi-Bouzid to increase the productivity of the flocks by reducing inbreeding and improving growth performance. Farmers who were beneficiaries of rangeland management subsides paid only the difference between the ram price and the equivalent of subsidies (Elloumi, 2005). The introduction of improved barley into the farmer production system allow to increase production at the farm level, improve soil quality especially nitrogen content and introduce among the farmers the habit of fodder production. Compared to traditional crops, improved barley varieties will significantly improve yields.

3.3. Data collection and source of data

The data were drawn from a sample size of 200 farmers in Sidi-Bouzid area, using a stratified random sampling technique; 100 adopters and 100 non-adopters of innovative technologies. The distribution of the sample collected and sample size from the different locations and technologies is displayed in Table (1).

Table 1. Distribution of sample by location

Farmers groups	Innovative Technologies	Location	No. of farmers
Adopters	Feed blocks	Hania	15
	Cactus	Zoghmar	18
	Automatic Waterer	Zitouna,	17
	Solar milk cooling system	Hania, Zitouna	7
	Improved rams	Zitouna,	23
	Improved barley varieties	Regueb,Zitouna	20
	Total	Sidi Bouzid area	100
Non-adopters	Without technologies	Sidi Bouzid area	100

Before launching the survey, the questionnaire was tested in the target areas. Pre-testing the questionnaire provided an opportunity to make some modifications and to improve the field survey. The questionnaire was used to collect the data through face-to-face interviews. The data collected was reviewed and verified. Then, data was coded and edited. Microsoft Excel and Statistical Package for Social Sciences (SPSS) were used for analysis.The information collected using the questionnaires covering several sections included information about farmer's socio economic conditions, natural capital, flock size, access to credit, engagement in community based organizations, farmers' knowledge of the innovative technologies, perception for technology adoption and attitudes for the technology transfer strategies.

3.4. Conceptual Framework: 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, 1990). 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:
$Y = f(X, e)$; Wheree is the stochastic disturbance term assumed to follow a logistic distribution (Amemiya, 1985).

The Logit model is specified as follows: $\Pr(D_i = 1/X) = \frac{e^{X'\beta}}{1+e^{X'\beta}}$

Y = [1: Adopter, 0: Non-Adopter]

Where β is a vector of parameters to be estimated, X is as defined in equation (1). The logit model is estimated by maximum likelihood (ML), assuming independence across observations and that the ML estimator of β is consistent and asymptotically normally distributed. However, the estimation rests on the strong assumption that the latent error term is normally distributed and homoscedastic.

3.4.1. Description of variables and hypotheses used in Logit model

The innovative technologies were influenced by technical, economic, social, and institutional factors. The model included seven illustrative variables and represented the factors mentioned that are supposed to affect the adoption of innovative technology in the study area (Table 2). These variables were:

AGE: is a quantitative variable. Age was hypothesized to have a negative relationship with the propensity to adopt precision agriculture technologies. The general notion found from the introduction of most new technologies both within agriculture and outside of it is that older generations are the last to adopt them, while the younger generations typically embrace them more quickly.

EDU: is a qualitative variable. Education may promote adoption of new technologies by increasing household's access to information and ability to adapt to new opportunities. It is expected that EDU have a positive impact on adoption.

FEXP: is a quantitative variable. This variable measures the average of the livestock owners experiences' in dairy sector and would be expected to show a negative sign. This is indicating, as a result of the fact that most of the farmers adopting an innovative technology are young livestock owners, that those with long experience are more adhering to traditional methods of farming, and are less receptive to adopting modern technologies.

LABE: is a quantitative variable. This variable measures the size of the active-labor force. The presence of a larger active-labor, have a positive influence on the adoption of modern technologies.

CRED: is a qualitative variable. This variable measures the accessibility of livestock ownersto cash credit and consequently to innovative technologies. The CRED dummy variable would be expected to exert a positive influence on adoption of modern technologies.

MEMA: is a qualitative variable. Being a member of an association can help livestock owners to have information on modern technologies and to have also more opportunities to adopt them.

COWN: is a quantitative variable. This variable measures the number of cattle heads. Livestock owners with a high flock size have a higher propensity to adopt innovative technologies than the small livestock owners.

INCSO: is a qualitative variable. This variable measures if the breeder has non-agricultural activity (off-farm income) or only agricultural activity (farm income). The INCSO dummy variable may influence negatively or positively the adoption of modern technologies.

EXTSER: is a qualitative variable. This variable measures the accessibility of livestock owners to extension services. The CRED dummy variable would be expected to exert a positive influence on adoption of modern technologies.

SINF: is a qualitative variable that refers to the source of information about the technique (1: project manager, 0: others). The communication of information from the project manager to the livestock owners directly has an effect on the increased probability of adopting the technology.

Table 2. Variables used in the empirical binary Logistic model

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			
AGE	Household head's age	Years	-
EDUC	Educational background of the household head	Dummy (1 if yes, 0 if no)	+
FEXP	Household head's farming experience	Dummy (1 if farm income, 0 if non-farm income)	-
INCSO	Income sources	Dummy (1 if yes, 0 if no)	-/+
EXTSER	Extension services	Dummy (1 if yes, 0 if no)	+
LABE	Labor force size	Active labor force Numbers	+
CRED	Obtained credit	Dummy (1 if yes, 0 if no)	+
MEMA	Member of association	Dummy (1 if yes, 0 if no)	+
COWN	Cattle ownership	Number of heads	+
SINF	Source of technology knowledge	1, project manager, 0: Others	+

4. Results and discussions

4.1. Criteria for innovative technologies adoption decision

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. In this study, numerous technologies attributes were selected to understand their importance on the adoption decision of IT (table 3).

A Likert scale of five, strongly agree (5) and strongly disagree (1) was used to assess the above mentioned characteristics of adopters of innovative technologies at the targeted zone. The result indicates that the farmers evaluate differentially the adopted innovative technologies (Table 3). The farmers agreed to adopt feed blocks because it reduces risk, the technology is triable, reversible, easy to follow up and compatible with production system. However, this technology needs know-how. For cactus chopper, the farmers adopt this technology because it reduces production costs and risk, the technology is especially affordable, compatible, easy to implement and to follow up. The solar milk cooling system technology is adopted because it has environmental benefits and the support of agricultural policies (subsidizes), this technology is triable but complex, not affordable and needs know-how. The farmers agreed to adopt improved rams technology because it increases profit, is communicable, easy to implement and follow up and has the support of agricultural policies. The improved barley variety is adopted by farmers because it reduces risk (high temperature), increase profits and is easy to implement and to follow up and has the support of agricultural policies. The farmers agreed to adopt automatic waterer because it reduces risks and is easy to follow up, compatible, communicable and Triable. However, this technology needs know-how.

Table 3. Criteria for innovative technologies adoption decision

	Feed blocks	Cactus chopper	Solar milk cooling system	Improved rams	Improved barley varieties	Automatic waterer
Easy to implement	3,1	4,5	3,1	4,4	4,5	4,2
Easy to follow up	4,1	4,5	3,7	4,5	4,5	4,7
Compatible	4,1	4,7	3,2	4,5	4,6	4,7
Agricultural policies support	3,2	3,1	4,7	4,5	4,7	3,1
Complex technology	3,7	1,2	4,7	1,9	1,8	3,2
Environmental benefits	3,1	2,8	4,8	3,0	3,2	3,2
Reduce risk	4,6	4,8	1,1	1,1	4,8	4,9
Needs know-how	4,6	2,7	4,6	1,7	3,2	4,2
Affordable	3,0	4,9	1,1	3,6	4,1	3,1
Communicability	3,9	4,5	4,1	4,5	4,2	4,2
Triable	4,4	4,8	4,7	3,9	4,5	4,2
Reduces production costs	3,8	4,8	3,2	3,0	1,0	2,1
Increase profits	3,9	4,2	2,7	4,5	4,1	3,7
Divisibility	2,9	4,2	1,0	1,0	1,0	1,9

4.2. Descriptive Statistics

Table (4) presented descriptive statistics for the variables used in this study. There are three major columns showing a description of the total sample, adopters of innovative technologies (IT) and non-adopters. Within these columns are the variable means and their standard deviations for the total sample, IT adopters and non-adopters. The average age of the household head for the total sample was 47 years while for IT adopters, it was 44 years. For the non-adopters, the household head’s average age was about 51 years. The level of education of the household head was categorized into two levels; educated and uneducated. An average of 88% of farm households that adopted IT had acquired at least primary education. The level of education for total sample was high (71%). For the non-adopters, the household head’s education level was about 53%. The average farm experience of the household head for the total sample was 20 years while for IT adopters, it was 23 years. For the non-adopters, the household head’s average farm experience was about 53 years. The average labor force size for the total sample and for both groups was about 4 members. Results show that about 44 % of the households in the total sample had off-farm income while 58% of IT adopters and about 29 % of the non-adopters had only farm income. In terms of cows owned, the average of the flock size was about 13 heads while for IT adopters, it was 18 heads. For the non-adopters, the average was 8 heads. Concerning institutional factors, the majority of IT adopters had access to extension services (91%). However, almost a third of the IT adopters had a member of association and had access to loans. In addition, results show that 76 % of IT 58 had access to information about technologies from project manager.

Table 4. Descriptive statistics of variables used

	Total sample		**Adopters**		**Non-adopters**	
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
AGE	47,60	11,799	43,81	9,901	51,39	12,361
EDU	0,71	0,457	0,88	0,327	0,53	0,502
FEXP	20,18	10,429	17,60	8,633	22,76	11,431
LABE	3,87	2,138	3,90	2,190	3,83	2,094
INCS	0,44	0,497	0,58	0,496	0,29	0,456
COWN	13,18	18,273	18,32	23,873	8,04	6,924
EXTSER	0,71	0,455	0,91	0,288	0,51	0,502
MEMA	0,30	0,457	0,36	0,482	0,23	0,423
CRED	0,28	0,450	0,34	0,476	0,22	0,416
SINF	0,58	0,496	0,76	0,429	0,39	0,490

4.3. Binary regression model results

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 test to reconcile the logistic regression model. The results of the model are given in Table (5). The overall percentage of correct predictions is about 78.5%. The *p*-value 0.579 uses the Hosmer and Lemeshow Goodness-of-Fit Test, which is computed from the Chi-square distribution with 8 degrees of freedom (d.f), confirm that the model’s estimates fit very well the data. This implies that we accept the null hypothesis that there is no difference between the observed values and the estimated values of the dependent variable (Sidibe, 2005). The column, exp (B), in Table (5) 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 table (5) showed that 8 explanatory variables were found to be significant at the level of 1% and 10%. These were EDU, EXTSER, COWN and SINF variables which showed their significance at 1% and FEXP and MEMA at 5% and Age and INCS at 10%. The rest of the variables (LABE and CRED) were consistent in terms of reference but did not prove their significance at the level of the model. The logistic regression equation is expressed as following:

ADOP = -2,421 - 0,033 AGE + 1,775 EDU -0,053 FEXP -0,012 LABE +0,725 INCS +0,118 COWN +1,665 EXTSER +1,016 MEMA -0,132 CRED +1,495 SINF

Results showed that age is statistically significant at affecting adoption of IT. The negative sign of the coefficient of age of the household head implies that the age of the household head decreases the odds of adopting IT. This result is in conformity with literature review where younger farmers have a higher propensity to adopt technologies than the older farmers. The variable EDU is statistically significant and positive affecting adoption of IT. This implies that adoption increases when the farmer have at least a primary level of education. This result confirms the literature review of the positive influence of the education farmer on adoption technologies. The variable labor force size (LABE) is statistically non-significant and have no impact on the decision to adopt IT. This seems to be explained by the fact that farmers don’t need much labor force especially for the mechanized technologies.As hypothesized, the farmer experience (FEXP) coefficient was also found to be significant and negatively correlated with adoption decision at the 5% level of significance. The result confirm the fact that most of the livestock owners adopting an innovative technology are young, those with long experience are more adhering to traditional methods of farming, and are less receptive to adopting modern technologies.The income sources INCS (availability of off-farm income) is statistically significant at affecting adoption of IT in Tunisia. Results indicate that off-farm incomes increase the odds of adopting IT among farmer. This seems to be explained by the fact that farmers’ major sources of income are off-farm activities and that they would more likely invest in agricultural technologies. In general, farmers with high income don’t need to have access to loans and are more likely to adopt IT.The cattle’s ownership COWN is statistically significant at affecting adoption of IT in Tunisia. The adopting increase in variable COWN by one unit will increase the probability of IT adopting by 1.125times. Results indicate that larger farmers that have large flock size of cattle would more likely adopt CT in Tunisia especially for the technology with high cost (Solar powered milk cooling technology, feed block manufacturing machine).The extension services variable EXTSER was also found to be significant and positively correlated with the adoption decision at the 10% level of significance. This implies that adoption increases when farmer have access to extension services. This result indicates the major roles of extension services on dissemination of innovative technologies in Tunisia. The association member variable MEMA was statistically significant at affecting adoption of IT in Tunisia. This indicated that the adoption of IT increased when the farmer is a member of an association. In this direction, this form of organization can help their members to have information about modern technologies, to give some advantages in terms of access to credit and to sustain the development of the sector by a trilogy principle where farmers, researchers and policy makers interacted together to find the optimum solution that fits the expressed needs of its members. The results showed that institutional variables such access to credit (CRED) have no impact on the decision to adopt IT. This indicates that there are many constraints for farmers to have access to credit in Tunisia (lack of land title, high interest rate, etc.). The source of technology knowledge variable SINF is statistically significant at affecting adoption of IT in Tunisia. This indicates that the adoption of IT increased when the information on technology was obtained directly from the project manager. This result confirmed the hypothesis that the project manager has the most comprehensive information on technology and is the most convincing for its adoption. Project manager needed to be more involved in the training of farmers for enhancing the adoption decision.

Table 5. Parameter estimates of the binary logistic regression model for factors influencing adoption of innovative technologies**.**

Variable	**B**	**S.E.**	**Wald**	**Sig.**	**Exp(β)**
AGE*	-0,033	0,020	2,796	0,095	0,968
EDU***	1,775	0,504	12,404	0,000	5,899
FEXP**	-0,053	0,022	5,678	0,017	0,948
LABE	-0,012	0,094	0,017	0,896	0,988
INCS*	0,725	0,415	3,047	0,081	2,065
COWN***	0,118	0,035	11,089	0,001	1,125
EXTSER***	1,665	0,507	10,790	0,001	5,283
MEMA**	1,016	0,443	5,254	0,022	2,763
CRED	-0,132	0,439	0,091	0,763	0,876
SINF***	1,495	0,459	10,610	0,001	4,462
Constante**	-2,421	1,231	3,869	0,049	0,089

Hosmer and Lemeshow Test: Chi-square, 6.608; df., 8; Sig., 0.579; -2 Log likelihood ,159,842a; Cox & Snell R Square, 0.444; Nagelkerke R Square, 0.592; The overall percentage of correct predictions, 78.5%; *Significance at 10%. **Significance at 5%; *** Significance at 1%; Source: Own elaboration from model results (2018).

5. Conclusions and Recommendations

For a long time, the question of technology dissemination has been posed keenly by decision makers in agriculture and especially in the livestock sector where productivity remains low. In addition, numerous development projects promoting innovative technologies have been installed in the arid zone characterized by difficult climatic conditions. However, the majority of farmers stop using the innovative technology once the project achieved. This study was conducted to enhance our understanding of factors influencing the adoption of innovative technologies in an effort to provide insights on pathways to increase their adoption in Tunisia. The Results of binary logistic regression showed the importance of economic, socio-demographic and institutional characteristics of farmers in the adoption of IT. The main factor contributing to adoption of innovative technologies is education. According to the national statistic in 2014, the illiterate rate in this area was about 29.2% for the population of Sidi-Bouzid governorate. This rate is higher in the rural area. This result incited the decision makers to pay more attention to the education level of farmers, to guide the techniques towards the educated farmers, which positively reflects on the possibility of adopting innovative technologies. In another way, it is essential to reinforce the adult literacy program for farmers, initiated by the government in 2000 especially in the arid area of Tunisia. It is also necessary to combat the number of young people who drop out of the school system early in the rural area. The negative sign of the coefficient of the variable AGE of the farmers implies that there is a time in life of the household head, when age would no longer positively affect the adoption of agricultural technologies, the relationship that relates to the life cycle hypothesis in economic theory (Ng'ombe*et al.,* 2014). The lessons from this study are the need to focus on targeting the young farmers group when promoting an innovative technology. In this direction, one of the success conditions for technology adoption is to collaborate firstly with young farmers and in the second stage with the older ones. Otherwise, the farmers face many challenges such as weather conditions, high prices of agricultural inputs, low productivity and low selling price which implies in abandonment of agriculture to young people. The government should give a lot of encouragement to young farmers to remain in the agricultural activity and then boost the technology dissemination.

The study showed the importance of the off-farm income in the adoption of IT. The low farm income is an important constraint for farmer to access to technology. In addition, the majority of farmers in Sidi-Bouzid are small with an average of herd size less than 8 cows per farmer. The farmers whose income was received as in-kind were found to be more likely to adopt innovative technology in the absence to the access of credits. In this context, government should improve the farm income of farmers to encourage technologies adoption. The results showed that the larger farmer is more likely to adopt than small farmer. Thus more extension efforts to promote IT should be directed to big farmer where adoption is easier (than small farmer) and can last a long time once the benefits of the international development project (payment of labor, granting of inputs, etc.) are stopped. The study showed the importance of the institutional variables on the decision to adopt IT. The participation of farmers in associations has a positive influence on the technology adoption. It helped introduce appropriate legislation benefiting livestock from national incentives and it provides an opportunity for the integration of smaller, poorer producers to improve their livelihoods. The association volunteers to be the guarantor for small flock owners who are in need for loans from the bank.However, the number of agricultural association in Tunisia is very low about 1267 for the Agricultural Development Groupings (GDA) and 177 for the Mutual Agricultural Services Company in 2012, the two major forms of organization in Tunisia. The government should modify the status of these organizations to have more flexibility and should give more advantages to farmers for becoming members of these organizations. The results showed also the important role of extension services on the adoption decision. In this direction, the Government should provide agricultural extension with sufficient financial and material resources, human resources and adequate training on modern technologies. In addition, strengthening the link between research activity and extension activity through a participatory approach where all stakeholders are included (researchers, extension agents, civil societies, public and private institutions, targeted farmers, etc.) is indispensable to enhance the adoption of IT.Extension approaches' components include access to technical information, to market information, and to inputs (improved seeds, livestock management, or fertilizer).Actually, appropriate extension approaches with most desirable impacts on technology adoption, agricultural productivity and households (including women and youth) livelihoods are urgently needed. Understanding which extension approaches has the greatest impacts will help improve future out scaling efforts. A strategy should be developed on how to implement an improved extension approach in a cost effective and gender sensitive way. The source of technology knowledge variable SINF is statistically significant and positive at 1%. This indicates the important role of accurate and sufficient information on the adoption of innovative technology (benefits, risks, Manuel of use, advantages, costs, etc.). In most cases, the innovative technology is introduced to farmers through a development project. To enhance the adoption of innovative technologies, the Government should intensify training programs for farmers and for extension agents with the collaboration of project manager. Otherwise, the adoption of any technology remains dependent on its financial feasibility and its adaptation with the farmer's environment.

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