# The adoption of water-saving irrigation technologies in the Mitidja plain, Algeria: An econometric analysis

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### Abstract

*This study aims to identify and analyze the major determinants that affect the adoption choice, rate and intensity of water-saving irrigation technologies (sprinkler and drip irrigation techniques) available in the western part of the irrigated perimeter of Mitidja Plain, Algeria. A sample of 136 farmers (28.75%) was randomly selected and surveyed using a structured questionnaire. Three econometric models were used, namely the Logit, Tobit and Poisson regression models. The main findings of the resulted models indicated that capital constraints (credit access, investment costs and subsidies) along with some human capital aspects (age, educational level) and water extraction cost, are the main determinants expected to influence the WSIT adoption choice, rate and intensity in the study area. These results will help to prioritize the factors that affect adoption decisions and provide insights for improving the crop and water productivity.*


***Keywords***: *Water-saving technologies, Water productivity, Irrigated perimeter, West Mitidja, Algeria.*

## 1. Introduction

For all of its consumers, including farmers, residential customers and industrial producers, water is a vital and scarce resource. The agricultural sector in Algeria is by far the largest user of total water[1] and has the most important contribution in the Algerian economy. It accounts about 12.2 percent of the GDP and employs 25 percent of the country's labor force (Bessaoud *et al.*, 2019). Algeria is one of the southern Mediterranean countries having at the Northern part a Mediterranean humid climate, whereas the rest is located in arid and semi-arid zones. All over the country, average rainfall is 89 mm/year (FAO, 2015). It became a well-established fact that an insufficient irrigation is one of the major constraints of agricultural productivity in Algeria.

Irrigation technologies such as sprinkler or drip irrigation may significantly boost the efficiency of water use in crops production. The adoption of irrigation technologies in agriculture is an important process for both economic and environmental reasons such as increasing farm productivity and saving water resources. Efficient water supply systems, such as drip irrigation, can contribute to increasing crop yield

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[1] Based on FAO (2015).

potential and enhancing crop water and fertilizer use efficiency (Badr *et al*., 2010). They are techniques that improve efficiency and productive use of inputs. Particularly, the drip irrigation technology has been found to have a significant impact on resource savings, cultivation costs, crop yields and farm profitability (Shrestha & Gopalakrishnan, 1993; Kumar & Palanisami, 2010). The adoption of irrigation technologies is frequently considered as a key to improve the efficiency of water usage in agriculture and reducing the use of scarce inputs (Cason & Uhlaner, 1991), consequently maintaining current output levels. Moreover, such irrigation technologies can increase the overexploitation of groundwater resources. Hence, new irrigation technologies reduce the use of water locally, but the subsidies push towards an extension of the irrigated surface, with negative impacts on the sustainable use of groundwater, more than half the aquifers in Algeria and Morocco, and about one quarter of the aquifers in Tunisia are overexploited (Kuper *et al*., 2016, Bouarfa *et al*., 2020).

Policy makers in developing countries have been attempting to promote, by several means, the adoption of new irrigation technologies. In Algeria, the change in irrigation technologies has been supported since 2000 by subsidies between 50% and 60% of the investment amount for drip and sprinkler irrigation (MADR, 2018). The design of these incentives sought to reduce the financing effort required by farmers when adopting new irrigation technologies. It assumed that the farmer's ability to finance investment in water-efficient irrigation equipment is the major constraint to the adoption of modern irrigation technologies. Nevertheless, the area equipped with water-saving equipment has not been able to achieve the objectives set by the government programs through this strategy, which means that the public subsidy alone is not the driving force behind the adoption of water-saving irrigation technologies. Several adoption studies were conducted around the world, although studies on the adoption of drip and sprinkler irrigation techniques have been found to be limited in Algeria (with special reference to recent few studies such as: Belaidi, 2013; Benmihoub *et al*., 2016; Akli *et al*., 2019; Belaidi *et al*., 2019; Oulmane *et al*., 2020).

Despite the advantages of Water-Saving Irrigation Technologies (WSIT), as compared to the traditional irrigation systems, and the government's commitment and support to diffuse these technologies, the speed of diffusion is found to be far below expectations. Nevertheless, most of the irrigated area in Algeria remains irrigated with the traditional gravity technique. For example, in 2018, the area equipped with drip irrigation represents less than 25% of the total irrigated agricultural area (1.33 million hectares).[2] Gravity technique is gradually giving way to irrigation by pressurized systems (sprinkler and drip irrigation techniques) which has indeed increased from 21% in 2000 to 42%, of which 23% for sprinkler and 19% for drip irrigation in 2012, and then to 49% in 2014, and 43.07, 33.42 and 23.50 percent for gravity, sprinkler and drip irrigation respectively (FAO, 2015; MADR, 2018). Therefore, the present paper has addressed the following important issues: (*i*) what factors limit or enhance the adoption of water-saving irrigation technologies? (*ii*) what factors influence the intensity (area under WSIT) of adoption of water-saving irrigation technologies? and (*iii*) what policy actions must be taken to speed up the adoption of water-saving irrigation technologies?

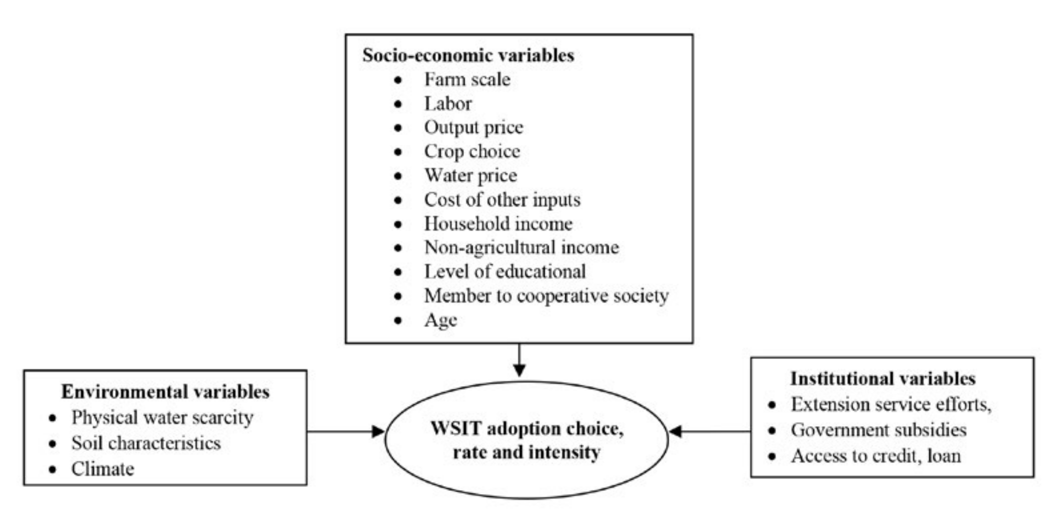
The paper is organized as follows: Section 2 presents the conceptual framework and a brief review of the literature on the adoption of WSIT. Section 3 explores the research methodology (data, variables and modeling procedures). Section 4 presents the main results with discussion. Section 5 concludes

## 2. Adoption of water saving irrigation technology: conceptual framework and literature review

Different factors and their relationships influence the adoption decisions of various technologies across space and time (Arega, 2009). These may include credit, land and labor constraints,

[2] According to MADR (2018) statistics.

Figure 1 - Conceptual framework for the determinants of WSIT.




risk aversion coupled with uncertainty about the impact on yields and prices of new technologies, restricted knowledge, lack of markets for farmers' produce, and tenure arrangements (Feder *et al.*, 1985). Other adoption determinants include education, experience and other socioeconomic characteristics along with structural characteristics of the farm such as soil quality and climate. Different studies have been conducted to find out the direction and the magnitude of the influence of different factors on farmers' adoption decision of agricultural technologies (Feder *et al.*, 1985; Feder & Umali, 1993; Sunding & Zilberman, 2001; van Oorschot *et al.*, 2018). Although some factors may have general applicability, it is not usual to develop a universal conceptual model that captures the process of technology adoption in all environments. The dynamic nature of the factors and the distinctive nature of socio-economic environment make it difficult to generalize about the causal relationship between determining factors and technology adoption.

The adoption of agricultural innovations results from a complex process characterized by the interdependence of several factors related not only to the availability of the innovation, its accessibility and its economic potential, but also to the farm-specific characteristics and its socio-economic, technical and institutional environment (Namegabe, 2006). Irrigation technologies are commonly divided into two groups in most previous studies: conventional irrigation, such as floods, border, and furrow irrigation, and modern irrigation, such as sprinkler and drip irrigation techniques. The variables used within the framework of our analysis are grouped according to three categories of factors: environmental, institutional, and socio-economic variables can be classified as the major factors influencing farmers' choice of water-saving technologies. Environmental variables affecting a WSIT choice include physical water scarcity, soil characteristics, and climate. Institutional variables include agricultural extension efforts, government subsidies or financing for the adoption of new technology, and demonstration projects (Wang, 2008). Socio-economic variables analyzed in previous studies include farm scale, output price, crop choice, water price, cost of other inputs, household income, non-agricultural income, and the educational level. The conceptual framework is shown in Figure 1.

As explained above, the decision to adopt an irrigation technology depends on a variety of factors including farm household characteristics, characteristics of the technology proposed, perception and the risk behavior of the farmer. In this study, we hypothesized that the most important factors affecting a WSIT adoption at farm level are as follows: Farmers' use of an irrigation technology is considered as a dependent variable. The major explanatory variables that are expected to affect farmer decision to adopt a WSIT are considered based on the empirical literature in many contexts. The previous empirical studies showed that numerous factors related to household characteristics, physical factors and socio-economic conditions are expected to affect the adoption of different irrigation technologies. The farmers' decision to adopt a WSIT was hypothesized to be influenced by a number of variables. In order to verify the existence of an effect of the three categories of factors on the adoption of WSIT, we propose the following hypotheses.

Farm size and human resources are the main variables that have an empirical relationship with farmers' decisions about whether or not to implement technology (Caswell, 1991; Dinar *et al*., 1992). In empirical studies, age, as a proxy for the experience, is one of the characteristics of farmers frequently studied. It is not possible to predetermine the path of the influence of this variable, but several empirical studies have found a negative relation between the technology adoption and the decision makers' age. Many studies have shown that variables of human resources, such as age and education level are positively associated with the adoption of irrigation technologies (Koundouri *et al*., 2006; Genius *et al*., 2014; Olen *et al*., 2015; Hunecke *et al*., 2017). For the WSIT adoption, the level of farmers' education is expected to play a crucial role. Trained farmers are more aware of (and able to learn) new technologies that are useful for their agricultural practices (Cason & Uhlaner, 1991). Producer characteristics, such as age and education, are also associated to decisions on irrigation techniques adoption (Koundouri *et al*., 2006). The study of Schuck *et al*. (2005) showed a positive relationship between the achievement of education and the adoption by Colorado farmers of sprinkler irrigation technology. Moreover, Zhou *et al*. (2008) also demonstrated that the level of education has an impact on the adoption of water-efficient technology by Chinese farmers, and Karami (2006) showed that a positive relationship exists between education and the adoption of sprinkler irrigation technique by Iranian farmers. Education is often argued as a variable that influences rates of adoption (Alcon *et al*., 2011). Human capital variables, such as education and years of experience, are indirect indicators of a farmer's ability to acquire and use information on new agricultural production technologies effectively. The higher is the age of a farmer; the lower is the probability to adopt new technology. Although older farmers have relatively richer experience of the social and physical environments, thus they are reluctant to new technologies than young farmers. Furthermore, another consideration could be raised which is the risk aversion that characterizes aged population with respect to younger one. Therefore, it is hypothesized that age of the farmer and WSIT adoption to have negative relationship. Therefore, it is expected that young farmers and high educational level will have significant effects on farmers' WSIT adoption.

Another major factor considered in adoption-diffusion research is farm size which affects adoption in several ways. Other factors interlinked with farm size are adoption costs, risk preferences, human capital, credit constraints, labor requirements, and tenure arrangement. Farm size is one of the key explanatory factors investigated by many empirical adoption studies. Although, theory provides few indications of the relationship between farm size and investment in new technologies. The theoretical literature suggests that large fixed costs reduce the tendency to adopt or slow down the rate of adoption by smallholder farmers. Farm size can have positive, negative or neutral effects on the adoption decisions of farmers. These effects depend on type and characteristics of new technology and the institutional settings in which the new technology is introduced. According to Richefort (2008), the relationship between farm size and adoption depends on fixed costs, risk preferences, knowledge, budget constraints, work time requirements, etc. The effects of farm size on the adoption are not always clear. Therefore, the effect seems ambiguous and depends on other factors. However, it can also be expected that farmers with small plots of land can be more interested to adopt drip irrigation to compensate their disadvantaged position with increased productivity using drip-irrigation technology. Nevertheless, empirical studies often show that large farms are more likely to adopt new technologies than small farms (Green *et al*., 1996; Shrestha & Gopalakrishnan, 1993; Marra & Carlson, 1987; Feder & O'Mara, 1981; Just & Zilberman, 1983). Hence, farm size is hypothesized to have positive relationship with WSIT adoption because households with larger farmland size can allot small plots for trial than those having small plot. On the other hand, large scale is an indication for wealth status of farmers and therefore it is expected that better-off farmers are likely to take risk than poor farmers.

The on-farm diversification is one the major factors studied in the empirical literature on agricultural technologies adoption. For the purposes of WSIT adoption, the effect of on-farm diversification may be harder to identify. A farmer with diversified crop portfolio may be more likely to adopt a risk-reducing technology. Likewise, a risk-averse farmer may both be better diversified and be more likely to adopt a risk-reducing technology (de Sousa *et al*., 2017; Li *et al*., 2020; Dzanku, 2018). If the new technology reduces yield risk, the probability of adoption will increase (Just & Zilberman, 1983). Irrigation equipment reduces dependence on variable rainfall, which reduces risk. Empirical results from Koundouri *et al*. (2006); Torkamani & Shajari (2008) and Salazar & Rand (2016) conclude that there is a positive and significant effect of production risk on adoption decisions, arguing that new irrigation technology is an input that reduces production risk. Therefore, it is hypothesized that on-farm diversification affects positively the WSIT adoption.

Technological characteristics, particularly installation costs, are also studied and are considered relevant to producers' choice of available technologies (Moreno & Sunding, 2005). Therefore, the cost of irrigation technology plays a significant role in farmers' ability to invest in irrigation equipment (Dinar & Yaron, 1992). Some studies show that a subsidy from an irrigation district can have an impact on adoption (Feder & Umali, 1993; Tiwari & Dinar, 2002). Government financial assistance is a policy instrument that the government uses as an incentive to adopt new agricultural technologies. Cost sharing between farmers and the government effectively reduces the price of irrigation technology and should lead to higher levels of use than without cost sharing. This relationship could be seen as tautological in the sense that cost sharing is conditioned by the use of irrigation technology. A conclusion that cost-sharing leads to a greater adoption effort, *ceteris paribus*, would confirm the expected response to lower prices. Therefore, it is expected that access to government subsidies will have a significant effect on WSIT adoption.

Another consideration discussed in a variety of adoption studies is the availability of labor. The number of family workers is an important production factor in family farming (Bainville, 2000; Hermelin & Lagandré, 2009). Therefore, a farm with a large workforce is more likely to introduce new technology. It is also argued that the availability of labor affects decisions in agriculture to implement technology (Feder *et al*., 1985). A farm with a large workforce is therefore more likely to introduce new technology. The direction of the labor effect on adoption decisions depends on the characteristics of the technology and the labor requirements of the technology. Some new agricultural technologies are labor-saving, while others may require more work compared to old technology. The WSIT is known for its labor reducing advantage in irrigation, thus it is more suitable for families with less labor force than households having more labor. Households with less labor are motivated to adopt WSIT to compensate their scarce labor. It is therefore hypothesized that farms with less labor are more likely to adopt the WSIT technology.

The degree of farmers' involvement in professional organizations acting in the agricultural sector can influence farmers' decisions. Agricultural cooperatives, extension clubs and other agricultural interest groups can raise awareness and influence their members to adopt new irrigation technologies. Based on much of the available theoretical evidence, farmers affiliated with agricultural cooperatives and extension clubs may be more aware of adoption and may therefore be more likely to adopt irrigation technologies. Participation in a cooperative allows farmers to join knowledge flow social networks, which tend to improve the adoption of new agricultural technologies (Bandiera & Rasul, 2006). Membership of farmers to cooperatives enables them to have broader access to information about new technologies. Moreover, cooperatives may have the voice to get assistance from different sources to encourage their members adopt new technologies. Thus, it is hypothesized that farmers who are members in professional organization are more likely to adopt WSIT than non-members.

If we consider the extraction cost of water as an economic determinant in the adoption of irrigation technologies, we can see that in all regions where the extraction cost of water is higher, the diffusion of resource-efficient technologies has been much faster than in regions where farmers have to pay less for water. This is widely corroborated with a high degree of consensus in the literature (Caswell & Zilberman, 1985, 1986; Dinar & Yaron, 1990; Caswell *et al*., 1990; Negri & Brooks, 1990; Schaible *et al*., 1991; Shah *et al*., 1995; Green *et al*., 1996; Green & Sunding, 1997; Schuck & Green, 2001; Carey & Zilberman, 2002; Foltz, 2003). In the case of groundwater pumping, the use of drip irrigation may increase over time as aquifers levels decline and water extraction cost rise (Shah *et al*., 1995). Caswell & Zilberman (1985) showed that farmers using groundwater were more likely to adopt sprinkler and drip technologies than those using surface water. Farms with access to surface water sources are more likely to opt for a gravity irrigation technique. The authors suggest that this result is not surprising since surface water is supplied by water districts that, in most cases, have adapted their distribution system to traditional technology. For wells, it is the depth and number of wells that are the most decisive factor in the cost of water supply. The depth and number determine the initial investment in drilling and pumping equipment, but also the energy costs. Accordingly, the following hypothesis has been derived: Using groundwater will have a significant effect on farmers' adoption of WSIT, and the likelihood of adoption increased with number of drilled wells.

## 3. Research methodology

### 3.1. *Data and variables*

To study the behavior of farmers regarding their adoption of a WSIT, as well as the factors that influenced this behavior, a well-structured questionnaire was designed to interview the heads or representatives of the collective EAC, EAI and private farms.[3] Using a method of stratified random sampling, we divided the ONID[4] farms database of scheme into three different strata with respect to land ownership type, and then a random selection of farms is proceeded for each stratum. This ensured a sufficient number of observations for each landownership group. Therefore, 136 farms were selected from the West Mitidja irrigation scheme, and the size of the sample selected from each group is shown in Table 1.

Data about the adoption of irrigation techniques are collected as the focus of study. Besides, farm and farmers' characteristics are collected. In addition, other information such as the number of drilled wells, production system, and policy subsidies also recorded. The data used in this study were collected from field surveys via face-to-face interviews in Mitidja Plain (Algeria) between January and November 2020. The agricultural domains of Mitidja Plains (T1), started functioning in 1989 with an area of 8 600 ha (of which 7 872 ha are irrigable), is divided into three sectors, South sector with 2 297 ha, East sector with 2 741 ha, and West sector with

[3] In 1987, socialist agricultural domains were divided into two types of agricultural units: State-owned collective farms (EACs) with at least three members and State-owned individual farms (EAIs) with infrastructure rights (equipment, buildings, livestock, orchards, citrus, etc.) except for land (Decree No. 87-19 of 8/12/1987). The State restituted the Algerian Revolution's nationalized land to its former owners in 1990 (under decree 90-25 of 18/11/1990). Under the 2010 Land Law, the perpetual use of public land, which was granted to beneficiaries under the 1987 Decree, has been transformed into a 40-year renewable concession. (in: *Journal Officiel de la République Algérienne*, no. 46 of 18/08/2010, no. 10-03 of 15/08/2010).

[4] For National Office of Irrigation and Drainage.

Table 1 - Selected sample of irrigation farms in the West Mitidja irrigation scheme.

| *Farm status* | *Total farms* | *Percentage (%)* | *Sample size* | *Sample percentage* | *Stratum percentage* |
|---|---|---|---|---|---|
| EAC | 376 | 79.49 | 114 | 83.82 | 30.32 |
| EAI | 26 | 5.50 | 11 | 8.09 | 42.30 |
| Private farms | 70 | 14.80 | 11 | 8.09 | 15.71 |
| Pilot farms | 1 | 0.21 | 0.00 | 0.00 | 0.00 |
| Total | 473 | 100.00 | 136 | 100.00 | 28.75 |

Table 2 - Definition and descriptive statistics of variables of the adoption model.

| *Variables* | *Data type* | *Definition* | *Mean* | *S.D.* |
|---|---|---|---|---|
| WSIT adoption | Binary | Farmer's adoption of water-saving irrigation technologies, 1 if adopted, 0 for non-adoption | 0.471 | 0.501 |
| WSIT rate | Censored data | Ratio of irrigated area under WSIT to operated land area and expressed as a percentage | 0.291 | 0.370 |
| WSIT intensity | Count data | Irrigated area under WSIT in hectares | 3.279 | 4.578 |
| Farm size | Continuous | Total operated farmland in hectares | 22.913 | 15.374 |
| On-farm diversification | Continuous | Herfindahl Index for on-farm diversification | 0.040 | 0.074 |
| Labor force | Continuous | The number of on-farm labor workers | 10.161 | 3.519 |
| Credit access | Dummy | 1 if farmer has an access to credit, 0 for no access. | 0.272 | 0.445 |
| Investment | Dummy | 1 if the cost of investment is a reason for not investing or equipping the whole farm area under WSIT, 0 otherwise | 0.478 | 0.499 |
| Age | Continuous | Age of the farmer in years | 62.323 | 10.090 |
| Education level | Categorical | Level of education of the farmer measured on a scale where 0 for none; 1 for Primary; 2 for Middle; 3 for Lyceum; 4 for University | 0.786 | 1.104 |
| Information source | Dummy | 0 if the information is from other farmers, 1 if the information is from extension services such as the Agricultural Services Department, agricultural Chamber, the irrigation agency ONID and technical institutes or other private sources such as private agricultural consulting firms, inputs suppliers. | 0.279 | 0.450 |
| Organization membership | Dummy | Dummy variable for membership of Water User Association, Farmer Cooperatives, The National Union of Algerian Farmers: 1 for members, 0 for non-members | 0.117 | 0.323 |
| Public subsidies | Dummy | 1 if the farmer has an access to public subsidies of irrigation technology; 0 otherwise | 0.323 | 0.469 |
| Drilled wells ratio | Continuous | Ratio between the number of drilled wells and the surface of the farm | 0.0814 | 0.0778 |

2 889 ha (Messahel & Benhafid, 2007). The study was conducted in the West Mitidja irrigated perimeter, located in the Blida Province. The irrigated area in Blida Province is 32 280 ha whose irrigation systems are distributed as follows 76.52, 11.04 and 12.44 percent for gravity, sprinkler and drip respectively (MADR, 2018). The irrigation water in the West Mitidja scheme (T1) is supplied from the Bouroumi Dam and is still an eminently agricultural zone. Most agricultural land in the West Mitidja perimeter belongs to the State domain but is cultivated by farmers holding land-use rights in the form of collective farms and individual farms. Many crop productions are practiced in the perimeter, where farmers earn their income from those farm products. The dominant types of crops cultivated in the region are cereals, citrus, orchards (peach, apricot, apple and pear), vegetable and greenhouse crops.

The data are considered to be representative of the overall rural population of the entire study region. The definitions and descriptive statistics of variables used in the adoption modeling are presented in Table 2. On average, farmers were 62.32 years old, 54.41% of them were illiterate, and have approximately ten workers. The mean farm size was 22.91 ha. The mean number of drilled wells was 1.15. Only 11.76% of farmers have been members of agricultural organizations, 27.2% with credit access and 19.87% had access to policy subsidies.

### 3.2. Empirical modeling procedures

The econometric models for the WSIT adoption decision can be specified as: $y_i^* = \boldsymbol{\beta}\mathbf{X} + \varepsilon_i$ . First, the study uses a binary variable for WSIT adoption, as a common measure in the empirical literature. In practice $y^*$ is not observed, but is estimated through the discrete variable $Y_i$ such that:

$$Y_i = 1 \text{ if } y_i^* \geq 0$$
$$Y_i = 0 \text{ if } y_i^* < 0$$

where $\varepsilon_i$ is assumed to be distributed according to a logistic distribution (with mean of zero and standard deviation of $2\pi/\sqrt{3}$). This assumption allows for the use of Logit estimation in the econometric model. Therefore, the general Logit model for the WSIT adoption decision is:

$$Y_i = \sum_k \beta_k X_{ki} + \varepsilon_i$$

where $Y_i$ is the indirect utility difference and is underlying latent variable that indexes the adoption choice of irrigation technology on a given parcel; $X_k$ is the vector of explanatory variables; $\beta$ is a column vector of parameters to be estimated and the stochastic error term $\varepsilon_i$ is distributed logistically with mean zero and variance normalized to $2\pi/\sqrt{3}$. The variable $Y_i$ is not observed but the adoption decision is, such that:

$$ADOPT_i = 1 \quad si \quad \sum_k \beta_k X_{ki} + \varepsilon_i \geq 0$$
$$\text{and } ADOPT_i = 0 \quad si \quad \sum_k \beta_k X_{ki} + \varepsilon_i < 0$$

Another dependent variable is used to analyze the WSIT adoption. It is a censored variable reflecting the farmland area fraction under WSIT, i.e. adoption rate. Its values are comprised between 0 and 1. Accordingly, the suitable econometric model is the Tobit regression (Gouriéroux, 2000; Greene, 2003). The Tobit model is specified as follows:

$$E\left(Y_i|\mathbf{X}\right) = \begin{cases} Y_i^* & if \quad 0 < Y_i^* < 1 \\ 0 & if \qquad Y_i^* \leq 0 \\ 1 & if \qquad Y_i^* \geq 1 \end{cases}$$

For both Logit and Tobit models, the marginal effects (M.E.) at means are computed and reported.

The factors affecting the intensity of WSIT use are considered empirically by a third dependent variable, namely: the number of hectares under WSIT in the farmland, which is counted data in nature. In this case, the Poisson regression is appropriate for analyzing such data.

Using the quasi-maximum probability method, the Poisson regression model can be estimated because it overcomes the problems associated with over-dispersion, which results in grossly deflated standard errors and inflated *t*-statistics in the output, and is consistent under this condition (Cameron & Trivedi, 2005; Wooldridge, 2015). Therefore, Poisson maximum likelihood estimation is used to estimate the regression coefficients, with the following specification:

$$E(Y=y)=\frac{e^{(-\mu)}\mu^{y}}{y}$$

where $y$ is number of hectares under WSIT, $\mu$ is the intensity or rate parameter. The distribution is stated as $p$ (μ). The distribution of the Poisson regression model assumes equi-dispersion, meaning that the mean and variance of the outcome are equal for a given covariate pattern, i.e. mean E(Y) = μ and variance V(Y) = μ (Hardin & Hilbe, 2015; Wang & Famoye, 1997). The standard approach of the Poisson regression is to use the exponential mean parameterization:

$$\mu_i = e^{X\beta}$$

where $\mu_i$ is the predicted number of hectares under WSIT, $\boldsymbol{X}$ is a vector of explanatory variables and $\boldsymbol{\beta}$ is a vector of unknown coefficients to be estimated. For the Poisson regression, the incidence rate ratios (I.R.R.) are computed and reported. Many adoption studies have employed Poisson models in determining intensity of adoption of technologies. For instance, Azumah *et al*. (2017) and Mensah-Bonsu *et al*. (2017) used Poisson to explain adoption intensity of climate change coping strategies and land and water management practices respectively; Jordán & Speelman (2020) used Poisson to explain adoption of irrigation technologies and the underlying diversity in terms of intensity of adoption; Mahama *et al*. (2020) also employed Poisson to estimate the determinants of adoption intensity of sustainable soybean production technologies.

Some robustness parameters should be considered for models assessment.[5] The study uses some relevant criteria for each model, namely Pseudo-$R^2$, adjusted $R^2$, log-likelihood, and likelihood ratio tests and *F*-statistic for overall significance.

## 4. Results and discussion

As preliminary analysis, the study of the WSIT adoption suggests a descriptive presentation of the use of water-saving technologies in the selected sample (Table 3). In the sample of 136 surveyed farmers, only 64 use WSIT, which represents about 47%. Indeed, in such choice studies, it is preferable that the favorable and unfavorable responses to a given criterion are in the proportions of 50%, but this only affects the affinity of the results and hardly intervenes in the global significance of variables estimated in the modeling results. The adoption of irrigation in Algeria is considerably encouraged by the government, which adopters benefit from subsidies that can go up to 60% of the equipment investment. However, constraints may limit access to this subsidy, such as land tenure. In the selected sample, 46.8% of the WSIT adopters received the subsidy.

The estimation results for WSIT adoption determinants of through Logit and Tobit models are shown in Table 5, whereas the OLS and Poisson regression results are shown in Table 6. The OLS use is just by way of comparison. The first column is for the explanatory variables. The regressions results are displayed in the remained columns. The chi-squared test statistic was significant at the 1% level for three models, implying joint significance of the variables. The correlation coefficient values have relatively high values for a multivariate analysis focused on cross-sectional data analysis. Notably, many of the 10 selected explanatory variables were statistically significant in the different models. Therefore, the models resulted are effective and explain appropriately the farmers' WSIT adoption phenomenon.

In order to test the existence of multi-collinearity, both continuous and discrete explanatory variables were checked using a Variance Inflation Factor (VIF). If the largest VIF is greater than 10 (or the tolerance is below 0.1) then this indicates a serious problem of multicollinearity (Bowerman & O'Connell, 1990). For the case of our study, the results of the tolerance and VIF tests (Table 4) indicate that the lowest observed value for tolerance is 0.131 and the highest value for VIF is 7.62. Furthermore, the correlation matrix results showed that there was no problem of strong association among the selected explana-

[5] The three models are estimated by using STATA 14.0 software.

Table 3 - Farmers' status of WSIT adoption.

| *Variables* | *WSIT adopters* | *WSIT non-adopters* |
|---|---|---|
| Number of farmers (%) | 64 (47%) | 72 (53%) |
| WSIT area in percentage | 61.87% | 0 |
| Mean WSIT area in ha | 7 ha | 0 |
| Farm size (mean) | 19.35 ha | 21.55 ha |
| Labor force by farm | 9.67 workers/farm | 10.45 workers/farm |
| Land area per worker | 2.02 | 2.06 |
| The percentage of farmers that accessed a credit on the total number of farmers of this group | 53.12% | 4.16% |
| The percentage of farmers who reported that the capital cost of investment is a reason for not investing or equipping the whole farm area under WSIT on the total number of farmers of this group | 29.68% | 63.88% |
| Age (mean) | 55 years | 69 years |
| Education level (median) | 2 i.e. middle school | 0 i.e. illiterate |
| The percentage of farmers are members in agricultural organizations on the total number of farmers of this group. | 17.18% | 6.94% |
| The percentage of farmers by sources of information on the total number of farmers of this group. | 46.90 % i.e from extension services | 88.90 % i.e. from other farmers |
| The percentage of farmers that received a subsidy on the total number of farmers of this group | 46.8% | 19.45 % |
| The total number of drilled wells of this group | 78 | 79 |

Table 4 - Variance Inflation Factor (VIF) for continuous explanatory variables.

| *Variables* | *Variance Inflation Factor (VIF)* | *Tolerance* |
|---|---|---|
| Farm size | 7.62 | 0.131 |
| On-farm diversification | 4.50 | 0.222 |
| Labor force | 2.30 | 0.434 |
| Credit access | 1.90 | 0.526 |
| Investment | 1.41 | 0.710 |
| Farmers' age | 2.03 | 0.491 |
| Education level | 2.11 | 0.474 |
| Information sources | 2.24 | 0.446 |
| Organization membership | 1.30 | 0.770 |
| Public subsidies | 1.73 | 0.578 |
| Drilled wells ratio | 1.56 | 0.642 |

tory variables (Appendix Table 1). The data have no serious problem of multicollinearity based on the tests outcomes.

Results from Tables 5 and 6 show that the explanatory variables are relevant in explaining the adoption decision. From the *z*-test statistics of the coefficient estimates in the models, it seems that generally, the selected farm structural characteristics, capital constraints, human capital aspects and extraction cost of water are significant considerations in the WSIT adoption choice in the study region.

The farm size, reflecting the wealth status of the farmers, is expected to influence WSIT adoption positively as WSIT involves large initial investment. This study shows that the farm size has negative relationships with the probability on WSIT adoption choice but is not statistically significant. The reason may have to do with the fact that cropping systems are heterogeneous in the study area. Thus, large or small farms are equally likely to be candidates for the choice of a WSIT.

Crop diversification is a measurement of the number of different crops under cultivation. To measure crop diversification, the Herfindahl-Hirschman index (HHI)[6] was used as a measure of diversification. It is possible that the decision to use saving technology is influenced by a farmer's decision to diversify and vice versa. The Herfindahl index is a variable included to measure farmers' risk exposure. It measures the amount of farmer diversification among crops as measured in cropping area. This Herfindahl index takes a maximum value of 1 for mono-cropping and decreases for better diversified farms. In other words, the measure of crop diversification has a value of 1 when there is a complete on-farm specialization and approaches 0 as the number of crops produced by the farmer gets larger. A low Herfindahl index indicates a diversified and less risky portfolio of crops. Farmers with higher levels of diversification would tend to be more risk-averse farmers. The results of Logit, Tobit and Poisson regression show that the crop diversification positively affected the adoption and negatively the intensity and rate of WSIT without statistical significance. The insignificant coefficients on "Herfindahl Index," used as a measure of on-farm diversification, provide little evidence to support the idea that farmers would adopt the technology to reduce risk.

Labor force affects WSIT intensity adoption positively and significantly at 1% level. Farms with larger labor force are more likely to adopt on a larger part of their irrigated area under WSIT. The I.R.R ratio indicates that, holding all other independent variables constant, the I.R.R of adopting saving irrigation technologies increases by a factor of 1.105 as the number of farm workers increases by one unit. The finding could be attributed to the fact that the sprinkler systems require significantly more labor than surface irrigation methods because the sprinkler lines must be moved at regular intervals to irrigate large fields and drip irrigation requires significant human capital for design and management. Farm workers are required to supervise the operation of the sprinklers, drippers and the booster pump. It should be noted that in study area, in general the technique of fertilization under WSIT is not well-known. It is therefore at an early stage, although the potential for use. The fact that farmers often manually fertilize their crops, WSIT is mainly used to convey water i.e. these farmers did not use all fertilizers under WSIT, which would imply a low impact on the economies of the irrigation labor. However, this result revealed that availability of labor would increase the intensity of adoption.

Based on estimation results, the coefficient of credit access is significantly positive in the models, implying that there is a positive relationship between credit access and the adoption choice, rate and intensity of a WSIT. In other words, as shown by Logit model results, if farmers had access to credit, the possibility that they will adopt WSIT increases by 83.1%. The marginal effect of Tobit model indicated that compared to other farmers, the likelihood of WSIT adoption rate by farmers with access to credit for irrigation technologies increased by 58.7%. From Poisson model results, as compared to the sample farmer who has not accessed to credit, the farmer who has access was higher, at a rate of 1.834 times, to increase their area with WSIT, *ceteris paribus*. Based on these results, it can be concluded that an attenuation of the financial constraints facing farmers may help to encourage the adoption of WSIT.

[6] This concentration ratio sums the squared shares of each crop in total area operated and can be expressed as follows: $HHI = \sum_{i=1}^{N}(p_i/P)^2$ where $p_i$ is the proportion of cultivated land area devoted to crop *i*, *P* is the area's total operated, *N* is the total number of crops. This index was chosen, among many other concentration indices, to measure on-farm diversification because of its simplicity of implementation, its adaptability to different types of crop diversification and because it possesses most of the characteristics of a good concentration index.

Table 5 - Estimation results for WSIT adoption determinants through Logit and Tobit models.

| *Explanatory variables* | *Logit Model* | | *Tobit Model* | |
|---|---|---|---|---|
| | *Coef.* | *M.E.* | *Coef.* | *M.E.* |
| Cons. | 22.602 (4.01)*** | --- | 3.918 (6.12)*** | --- |
| Farm size | −0.042 (−0.62) | −0.010 (−0.62) | −0.006 (−0.05) | −0.006 (−0.05) |
| On-farm diversification | 12.79 (1.51) | 3.164 (1.50) | −0.111 (−0.05) | −0.111 (−0.05) |
| Labor force | −0.013 (−0.10) | 0.003 (0.1) | −0.023 (−0.92) | −0.023 (−0.92) |
| Credit access | 5.643 (3.77)*** | 0.831 (10.39)*** | 0.587 (3.41)*** | 0.587 (3.41)*** |
| Investment | −2.485 (−3.16)*** | −0.544 (−4.07)*** | −0.365 (−2.73)*** | −0.365 (−2.73)*** |
| Farmers' age | −0.345 (−4.17)*** | −0.085 (−4.22)*** | −0.055 (−5.85)*** | −0.055 (−5.85)*** |
| Information sources | −2.519 (−1.71)* | −0.504 (−2.55)* | −0.071 (−0.38) | −0.071 (−0.38) |
| Organization membership | −2.292 (−1.63) | −0.417 (−2.53) | −0.104 (−0.49) | −0.104 (−0.49) |
| Public subsidies | −0.906 (−0.90) | −0.215 (−0.95) | −0.188 (−1.19)* | −0.188 (−1.19)* |
| Drilled wells ratio | −2.27 (−0.43)*** | 0.562 (0.43)*** | −1.747 (−1.67)* | 1.747 (1.67)* |
| Number of obs. | 136 | | 136 | |
| Pseudo-$R^2$ | 0.591 | | 0.449 | |
| Adjusted $R^2$ | 0.474 | | / | |
| Log likelihood | −38.40 | | −72.52 | |
| LR $chi^2$ (df) | 111.24*** | | 118.21*** | |
| Cases correctly predicted | 89.0% | | / | |

*Note: Values in parentheses represent z-ratio for M.E. and Logit coefficient estimates, t-ratio for Tobit coefficient estimates. Asterisks *, ** and *** are significant at 10%, 5%, 1% level respectively.*

Moreover, the results confirmed that the investment costs[7] significantly decreased the likelihood of WSIT adoption choice, rate and intensity. Investment costs influenced negatively the farmers' adoption of a WSIT. The coefficient for the judgment from the farmer about the fact that the investment cost is a reason for not investing was significant and negative for the Logit, Tobit and Poisson models estimated at the level 1%, suggesting that farmers who have judgment of the high costs were less likely to adopt WSIT. Results of Logit model show that the probability of WSIT adoption was 54.4% lower when the cost increased by one unit. Tobit model also shows that the judgment of the high cost of adoption decreases the probability of the adoption rate by 36.5%. Finally, Poisson regression results demonstrate that area installed by WSIT was 51% lower when

[7] According to MADR (2018) statistics: The investment cost of one hectare of drip irrigation is estimated at 4 020.40 USD for open field vegetable crops, 3 885.34 USD for greenhouse and 1 740.79 USD for orchards or citrus. Screen and disc filtration costs 531.19 USD. A geomembrane basin with a capacity of 1 500 $m^3$ costs 7 439.61 USD. Rotary drilling well costs 148.79 USD by linear meter. The cost of investment of one hectare for vegetable crops in the integral sprinkler cover system costs 5 837.20 USD.

Table 6 - Estimation results for WSIT adoption determinants through OLS and Poisson models.

| *Explanatory variables* | *OLS Model* | | *Poisson Model* | |
|---|---|---|---|---|
| | *Coef.* | *M.E.* | *Coef.* | *I.R.R.* |
| Cons. | 5.087 (1.78)* | --- | 3.015 (5.85)*** | --- |
| On-farm diversification | −2.398 (-0.56) | −2.398 (-0.56) | −0.181 (−0.18) | 0.834 (−0.18) |
| *Labor forc*e | 0.289 (2.96)*** | 0.289 (2.96)*** | 0.100 (5.89)*** | 1.105 (5.89)*** |
| Credit access | 1.212 (1.42) | 1.212 (1.42) | 0.606 (4.88)*** | 1.834 (4.88)*** |
| Investment | −0.938 (-1.43) | −0.938 (-1.43) | −0.671 (−4.51)*** | 0.510 (−4.51)*** |
| Farmers' age | −0.090 (-2.32)** | −0.090 (-2.32)** | −0.051 (−6.79)*** | 0.950 (−6.79)*** |
| Education level | 2.314 (6.37)*** | 2.314 (6.37)*** | 0.413 (8.86)*** | 1.512 (8.86)*** |
| Information sources | −0.299 (-0.33) | −0.299 (-0.33) | −0.311 (−2.21)** | 0.732 (-2.21)** |
| Organization membership | −0.947 (-0.97) | −0.947 (-0.97) | −0.356 (−2.34)** | 0.700 (−2.34)** |
| Public subsidies | −0.825 (-1.07) | −0.825 (-1.07) | −0.315 (−2.55)** | 0.729 (−2.55)** |
| Drilled wells ratio | −3.317 (-0.82) | −3.317 (-0.82) | −1.689 (−2.22)** | 1.184 (−2.22)** |
| Number of obs. | 136 | | 136 | |
| F | 14.88*** | | / | |
| Pseudo $R^2$ | / | | 0.410 | |
| Adjusted $R^2$ | 0.506 | | 0.375 | |
| Log likelihood | −346.71 | | −315.70 | |
| LR $chi^2$ (df) | / | | 438.74*** | |

*Note: Values in parentheses represent z-ratio for M.E. and I.R.R for OLS and Poisson coefficient estimates. Asterisks *, ** and *** are significant at 10%, 5%, 1% level respectively.*

the cost increased by one unit. It means high costs are a truly key barrier of adoption with respect to capital input. This result implies that it is necessary to reduce the cost of the initial investment of a farmer for the adoption of WSIT to encourage effectively the promotion and the implementation of irrigation technologies.

The farmers' age significantly influenced the WSIT adoption choice, rate and intensity at 1% significance level and influences the adoption negatively, keeping other variables constant. As expected, older farmers had a lower probability of adoption of a WSIT. In terms of marginal effect, a unit increase in farmers' age resulted in a 8.5 % decline in the probability of WSIT adoption. Tobit model also shows that farmers' age decreases the probability of the adoption rate by 5.5%. In terms of WSIT use intensity, keeping other variables constant, the I.R.R. of this variable indicates that if the farmers' age increased by 1 year, the intensity of the number of hectares used by the farm would decrease by a factor of 0.95. This result could be explained by the fact that age is a factor of risk aversion, and reduces the choice of adoption of new technologies. It possible that young farmers are more willing to engage in risky activities like to invest in WSIT than older farmers. Besides, older farmers often have shorter planning horizons, resulting in a higher actualization rates that reduces the present-value of their returns investment, and they are likely to be hostile to change.

The information sources variable is significant at 10% and 5% level for Logit and Poisson models respectively and negatively related with WSIT adoption. The result is not consistent with the hypotheses that those farmers who get information from extension services and other institutions should have a higher probability to adopt such technologies. Our result corroborates the finding of (Dhehibi *et al.*, 2018), who found a negatively significant relationship between extension services and adoption of soil and water conservation techniques. According to Evenson & Westphal (1995), the transmission of information cannot be accomplished solely through the use of rules of thumb primarily employed by extension personnel; rather, it requires the formation of strong social networks among growers engaged in learning-by-doing. In fact, we don't know if extension personnel (from either private, or public extension agencies) target specific farmers who are recognized as being peers exerting a direct or indirect influence on the entire population of farmers in their respective areas. More specifically, the variable cannot assess whether the information was too theoretical, and not practical in applications. Equally important is a realization that this variable does not indicate the quality of information or the extension services. Further research is required in this regard to provide an explanation for this counterintuitive result.

Being a member in agricultural organizations affects the intensity decision of farmers negatively and significantly at 5% level. Membership in agricultural organizations decreases the probability of adopting irrigation saving technologies. Although a direct causation between membership in farm organizations and adoption of WSIT cannot be asserted, the variable may be considered mainly as a proxy for social networks and interaction between farmers. This most probably indicates that members do not support each other in the decision to adopt WSIT, a social network and exchange of personal knowledge on the benefits are low. A study of agricultural cooperatives in the Mitidja showed that the reasons for this disaffection of farmers are to be found in the fact that the leaders of these cooperatives only partially respect the management principles stipulated in the regulatory texts governing this type of institution. The value of the I.R.R indicates that by holding all other explanatory variables constant, each increase in the membership in agricultural organizations score by one unit would generate a decrease of the I.R.R of adoption by 0.70 times.

The educational level of the farmers, as expected, had a significant and positive relationship with the WSIT intensity at a 1% statistical significance in Poisson regression results. The education level improved the likelihood for more use of WSIT in farmland, *ceteris paribus*. Therefore, this implies that education is one of the key determinants for WSIT adoption. The results showed that the greater the farmers' education level, the greater the chance of high WSIT use, such as hypothesized and observed in other empirical studies. Farmers with high schooling level are more likely to have additional information concerning the WSIT use and more capacity to process information related to new technologies. In the same direction, the more educated farmers tend to have higher levels of managerial skills, which can lead to better resource allocation. According to the calculated results on the I.R.R., a one-unit increase of schooling led to a 1.52 times increase in the likelihood of more WSIT use intensity in the operated farmland.

The results from Tables 5 and 6 indicate that subsidy variable is at best significant at 10%, and negatively associated with WSIT adoption rate and intensity. Based on estimation results, the coefficient of policy subsidies is significantly negative in the model results, implying that there is a negative relationship between policy subsidies and the adoption of WSIT, in one case, the sign is the opposite of what is predicted. In other words, if farmers had access to policy subsidies, the possibility that they will adopt WSIT decreases. This is in contrary to the finding of Dinar & Yaron (1992) who found a positively significant relationship between subsidies for equipment, and adoption of WSIT. However, the study of Malik *et al.* (2018) found a negative impact of subsidies on the adoption of irrigation technology.

The negative and significant correlation between subsidies and WSIT adoption can be explained by the defection of a large part of the installed networks and subsidized because the lack of monitoring and control of irrigation networks subsided by equipment suppliers and the administration in charge of the subsidy. In 2005, the Agricultural Services Department carried out a verification operation on all the farms that had benefited from the irrigation technologies subsidy. The findings revealed the following: (*i*) a large part of the equipment supplied by the operators, particularly the distribution ramps, was of much lower quality, which accelerated their deterioration, agents often encourage farmers to purchase lower-quality systems with higher margins for dealers or manufacturers; (*ii*) Some networks were completely clogged and subsequently abounded by the farmers. The defection rate of subsidized networks has been estimated at 70% of the total installed. This explains the significant regression recorded in the allocation of subsidies or their suspension in 2008. The government supported farmers to acquire the WSIT, with an investment subsidy of 100%[8] initially (in 2000), as of 2004 the value of the subsidy was revised downward because the value of the subsidy was found to be higher than the prices practiced by suppliers for much of the equipment. At the end of 2006[9] the rate of subsidy was only 60% of the cost, a low rate of subsidy less than 40% between 2006-2009 (subsidy system was removed in 2008), and subsidy is 50% of the cost from 2014.[10] This may lead to the conclusion that the government programs' subsidies predict lower probabilities for WSIT. Such a conclusion would not be supported by the findings of previous studies that government programs providing financial or technical assistance are strong determinants of the adoption of conservation technologies (Amosson *et al*., 2009).

Finally, the use of irrigation water through a drilled well is one of the characteristic features in the study region (West Mitidja). Other types of access were observed in the study region, but different types of access coexist in the majority of farms (irrigation through drilled wells and dams). The variable of the drilled wells ratio reflects the use of groundwater from the Mitidja aquifer and the cost of extracting irrigation water. The results of the three models show that this variable has a negative and significant effect on the WSIT adoption, rate and intensity. In other words, as the farm area and number of drilled increases that imply the ratio of drilled wells on farm area decreases,[11] thus the probability of adoption WSIT increases. According to the computed marginal effects, results of Logit model show that the probability of WSIT adoption was 56.20 % lower when the drilled wells ratio increased by one unit, a one-unit increase of the drilled wells ratio leads to a 1.74 times decrease in the probability of WSIT adoption rate, and in terms of the I.R.R., lead to 1.78 times decrease in the likelihood of more WSIT use intensity in the operated farmland. We can conclude that the higher number of drilled wells (i.e ratio of drilled wells decreases) and therefore the higher the cost of extracting irrigation water affects positively the adoption, rate and intensity of WSIT. This result could be explained by when the extraction cost of water is relatively high[12] (usually because of expensive investment in drilled wells) the farmer has a greater incentive to use water-saving techniques. Conversely, all those who benefit from the very low cost of water from the ONID and obtained from the

[8] Ministerial decision no. 599 of 08/07/2000.

[9] Ministerial decision no. 259 of 26/05/2006.

[10] Ministerial decision no. 943 of 02/10/2014.

[11] It should be noted that bivariate correlations are made between the pairs of farm size and drilled wells with a Pearson correlation of 0.311, and farm size and ratio of drilled wells on farm size with a Pearson correlation of –0.173. The correlation is significant at the 0.01 and 0.05 level respectively. There is also a negative correlation between the pairs of drilled wells and ratio of drilled wells on farm size with a Pearson correlation of –0.132 (see Appendix Table 2).

[12] According to the ONID (2020), the cost of a $m^3$ of water from a Drilled Wells in the Matija is 0.037 USD by $m^3$, while the administered price of a cubic meter of water supplied by the ONID is set by law at 0.0148 USD/$m^3$, for water distributed by gravity and 0.0185 USD by $m^3$ for water distributed after pumping. (1 DA= 0.0074 USD).

irrigation networks connected to the dam, have little interest in investing in these same techniques. The main significant variables in both OLS and Poisson models point to the farmers with the highest probability of intensity adoption of WSIT are those who have the labor force and high level of education and the younger ones.

## 5. Conclusion

The study aimed to analyze empirically the factors that affect farmers' adoption choice, rate and intensity of water-saving irrigation technologies in West Mitidja, Algeria, among a sample survey of 136 farmers. Three econometric models of regression were used, namely: the Logit model (for a binary adoption choice of a WSIT), the Tobit model (for censored values of WSIT area) and Poisson models (for count data of WSIT area). The econometric models seemed to have very high levels of robustness and they are effective and explained the farmers' WSIT adoption phenomenon.

The main findings of the resulted models are as following: In terms of adoption choice, two factors that significantly and positively affect farmers' choice of WSIT adoption are: credit access and extraction costs of water. This is corroborated by findings of Genius *et al*. (2014); Alcon *et al*. (2011); Namara *et al*. (2007); Foltz (2003); Dinar & Yaron (1992) and Caswell & Zilberman (1985), who found a positive significant relationship between irrigation with drilled wells and access to credit. However, other factors such as investment and farmers' age have significant and negative effect technology adoption. The study confirms the finding of Zhang *et al*. (2019) and Hunecke *et al*. (2017), who found that investment and age had a significant negative relationship with technology adoption. Nevertheless, in terms of WSIT intensity, labor force, credit access and education level affect significantly and positively the WSIT intensity at farm level, whereas investment, ratio of drilled wells on farm size, information sources, organizations membership, subsidies and farmers' age have significant and negative effect on WSIT intensity.

The analysis presented in this study could provide useful policy implications for decision makers with intervention levers, which permit to improve the public action to preserve such common valuable resource, the irrigation water. Policy makers frequently are not well-informed about factors that could influence the adoption of new irrigation technologies. Nonetheless, this study provides some insights for the Algerian policymakers. The age and educational status of farmers were the key determinants for the WSIT adoption. The unexpected negative correlation between information sources, membership in agricultural organizations, subsides and adoption remains unclear. This finding could be explained by a low efficacy, or low relevance, of the policy subsidies, agricultural organizations and information provided. This indication should be evaluated by the local agricultural institutions. Thus, the extension and training services should be more targeted and possibly supported by the efficient identification of the farmers' influential peers to promote WSIT. Besides, the establishment and maintain of demonstration farms and areas, where the benefits of the promoted WSIT could be shown, and assessed with the farmers' participation, would raise awareness of WSIT. Even if capital costs are a significant barrier, there are alternatives to the current subsidy system that would avoid some of its current shortcomings. For example, the government could, alleviate the eligibility conditions, ease administrative process to obtain subsidies and increase it rates, which requires verification of product purchase and use. Alternatively, farmers can either be provided with interest-free loans for the entire cost of WSIT, administered through existing financial institutions, or provided with conditional cash transfers.

Although, whether or not adopting modern water-saving technologies (such as sprinkler or drip irrigation techniques) conserves water is still an ongoing controversy. The public policy about the irrigation water permits the increase of the agricultural production, to better value the water as well at the level of the farms as at the national level, on the other hand, one increases involuntarily, and against the expectations, the global consumption of water, at the expense of the groundwater, especially in Algeria where nearly 90% of the irrigated farmland areas depend on groundwater. The recent literature shows that even when water is saved at plot-level, water demand is generally increased at other scales, such as the farm or regional scale (Ward & Pulido-Velazquez, 2008; Batchelor *et al*., 2014). Caswell & Zilberman (1986) confirm that switching to sprinkler or drip irrigation techniques from border or furrow irrigation saves water at the field level under certain circumstances. Therefore, under some hydrologic conditions, adopting water-saving technologies, either traditional or modern, lead to water saving on farm-level fields. Additional regulatory mechanisms are needed parallel with the subsidy policy of WSIT, for example, contracts between the Government and farmers on the implementation of WSIT and the extension of the irrigated area, the regulation of individual groundwater withdrawals through incentives in which farmers undertake to declare their drillings, particularly in the case of illegal drillings, and install meters. The implementation of a tax on underground withdrawals according to the risk of overexploitation of the water table.

This study has clearly some limitations that offer many research perspectives. In addition to the influence of socio-economic and financial factors, other determinants related to the profitability of the investment, production risk, and agricultural product prices, land tenure issues may influence farmers to adopt WSIT. In addition, results of our static models using cross-sectional data do not capture changes in adoption decisions over time. Dynamic models using panel data might be in order to effectively describe the adoption and diffusion across both time and space. Future research would adequately describe these factors and how they related to the adoption process. These ambitions would be difficult to accomplish with the current data set. They require a larger data set and the inclusion of time dimension in the data. Besides, this research was limited to the Mitidja region, but it will be enlarged to other irrigated areas with different climatic zones and cropping systems in order to compare with our case study and to be able to generalize our findings.

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## Appendix

Table 1 - Correlation matrix of explanatory variables.

| *Variables* | *Investment cost* | *Credit access* | *Education level* | *Organization membership* | *Information sources* | *Public subsidies* |
|---|---|---|---|---|---|---|
| Investment cost | 1.0000 | | | | | |
| Credit access | -0.3203 | 1.0000 | | | | |
| Education level | -0.4431 | 0.5086 | 1.0000 | | | |
| Organization membership | -0.2123 | 0.3922 | 0.2366 | 1.0000 | | |
| Information sources | -0.3006 | 0.5399 | 0.4779 | 0.1286 | 1.0000 | |
| Public subsidies | -0.2841 | 0.4249 | 0.3909 | 0.0890 | 0.6202 | 1.0000 |

*Source: Author's elaboration from field survey (2020).*

Table 2 - The Pearson correlation coefficient.

| *Correlations* | *Farm size* | *Drilled wells* | *Ratio of drilled wells on farm surface* |
|---|---|---|---|
| Pearson Correlation | 1 | 0.311** | -0,173* |
| Sig. (bilateral) | | 0.000 | 0.044 |
| N | 136 | 136 | 136 |
| Pearson Correlation | 0.311** | 1 | -0.132 |
| Sig. (bilateral) | 0.000 | | 0.126 |
| N | 136 | 136 | 136 |
| Pearson Correlation | -0,173* | -0.132 | 1 |
| Sig. (bilateral) | 0.044 | 0.126 | |
| N | 136 | 136 | 136 |

*Source: Author's elaboration from field survey (2020).*