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RESEARCH ARTICLE

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# Farmers' willingness to pay for surface water in the West Mitidja irrigated perimeter, northern Algeria

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## Abstract

Algeria is among the most water-stressed countries in the world. Because of its climatic conditions, irrigation is essential for agricultural production. Water prices paid by farmers in public irrigation districts are very low and do not cover the operation and maintenance (O&M) costs of the irrigated perimeters, thus leading to the deterioration of these infrastructures. The objective of this paper is to analyse whether farmer's in the West Mitidja irrigation district in northern Algeria would be willing to pay more for surface water in order to maintain the water supply service in its current conditions. We estimated farmers' willingness to pay (WTP) for water using data from a dichotomous choice contingent valuation survey to 112 randomly selected farmers. Farmers' responses were modelled using logistic regression techniques. We also analysed which technical, structural, social and economic characteristics of farms and farmers explain the differences in WTP. Our results showed that nearly 80% of the surveyed farmers are willing to pay an extra price for irrigation water. The average WTP was 64% greater than the price currently paid by farmers, suggesting some scope for improving the financial resources of the Mitidja irrigated perimeter, but insufficient to cover all O&M costs. Some of the key identified factors that affect WTP for surface water relate to farm ownership, access to groundwater resources, cropping patterns, farmers' agricultural training and risk exposure.

**Additional keywords:** water demand; water economics; irrigation; dichotomous choice model; logistic regression.

**Abbreviations used:** CV (Contingent Valuation); DA (Algerian Dinar); EAC (Exploitation Agricole Collectif/Public collective farm); EAI (Exploitation Agricole Individuelle/Public individual farm); ME (Marginal Effect); ONID (Office National de l'Irrigation et du Drainage/National Office for Irrigation and Drainage); O&M (Operation and maintenance); WTP (Willingness to Pay).

**Authors' contributions:** Conceived the research and designed the survey: MA, JC and SB. Collected and codified the data: MA. Analysed the data and drafted the manuscript: MA and JC. Critically revised the manuscript: SB. Wrote the English version of the manuscript: JC.

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# Introduction

Algeria is among the most water stressed countries around the world. Average annual water availability is 404 m$^3$ per inhabitant (Hamiche *et al.*, 2015), which is far below the World Bank's scarcity threshold, set at 1000 m$^3$/inhabitant/year (Drouiche *et al.*, 2012). Effectively available renewable resources are estimated at 15,000 Mm$^3$/year, most of which correspond to northern Algeria (7,400 Mm$^3$/year of surface resources and 2,600 Mm$^3$/year of groundwater). Groundwater resources in the southern Sahara region are estimated at 5,000 Mm$^3$/year (Hamiche *et al.*, 2015). In addition, non-conventional sources (desalinised brackish and sea water and recycled wastewater) have an increasing potential for providing nearly 2,000 Mm$^3$/year water resources in the future (Hamiche *et al.*, 2015; FAO, 2016).

The country is exposed to very unfavourable climatic conditions, characterized by scarce, variable and unevenly distributed (both spatially and temporarily) rainfall, and a high evapotranspiration rate. In such scenario, irrigation is essential for agricultural production. In fact, it produces half of the country's value of agricultural production using only a 14.5% of agricultural area (1.23 million hectares out of 8.5 million hectares). Large-scale irrigation districts, totalling an area of 270,000 ha (Hamiche *et al.*, 2015), were created by public initiative, both before and after the country's independence, and are managed and maintained by the government. The rest of the irrigated land in Algeria corresponds to small and medium irrigated areas that are directly managed by farmers.

With the objective of increasing national agricultural production and food self-sufficiency, the Government of Algeria has traditionally supported the development of both existing and new public irrigated areas. In the 1980s, it started a decentralization process to improve water management in irrigated areas (Laoubi & Yamao, 2009b). Later in 1996, a new Water Act, based in principles of integrated water resources management, was passed. Among other issues, it included the use of water tariffs to recover the costs of water supply and ensure the financial sustainability of irrigation districts (Laoubi & Yamao, 2009b). Subsequently, in 2005 the Government of Algeria created the *National Office for Irrigation and Drainage* (ONID) to take responsibility of the operation, management and maintenance of the country's public irrigated areas, with special focus on improving water use efficiency and water supply quality and reliability. ONID is mainly financed through water tariffs and public subsidies from the government.

In addition to increasing the storage capacity of surface resources and subsidizing modern irrigation technologies, the Algerian Government has supported irrigation by maintaining the same agricultural water tariff since 2005. Farmers pay a binomial water tariff with a fixed rate that ranges between 250 and 400 Algerian Dinars (DA) per hectare (2.12 to 3.4 €/ha/year) and a volumetric component that ranges between 2.0 and 2.5 DA/m$^3$ (0.0169 to 0.0212 €/m$^3$), depending on the irrigated area considered. The final tariff paid is established taking into account the specific characteristics of each irrigated perimeter and the crops cultivated in it, according to the rules set in the Decree 05-14 of the 9th of January 2005.

Such low water tariffs do not cover the operation and maintenance costs of the irrigated districts (Laoubi & Yamao, 2009b; Benmihoub & Bedrani, 2012). For example, Laoubi & Yamao (2009b) estimate cost recovery rates for several Algerian public irrigation schemes to range between 31 and 93%. This low cost-recovery rate is progressively leading to the deterioration of their water storage and distribution infrastructures. Moreover, water tariffs paid by farmers represent less than 10% of direct crop production costs (Bouarfa *et al.*, 2010; Imache & Belarbia, 2010), what does not encourage farmers to save water and to use it efficiently.

In a context of increasing water scarcity and variability, as foreseen by climate change scenarios, the water policies currently in place in Algeria, such as the development of new reservoirs, the expansion of the irrigated area and the strong subsidisation of water costs, are unlikely to significantly contribute to water security, and thus to the declared objective of increasing food security in the country. Alternatively, water policies should increasingly focus on reducing risks and increasing water use efficiency by using well-designed, flexible, robust and equitable water allocation mechanisms and economic instruments, such as water pricing and markets (OECD, 2014).

Increasing water tariffs is thus essential to maintain the infrastructures of public irrigated areas of Algeria and ensure a more efficient water use. Consequently, ONID is trying that the Algerian Government revises water tariffs upward. This is not a specific problem of Algeria. Around the world, irrigation water tariffs are usually low, and many water supply services are either subsidised by governments or provided with low quality and reliability (Molle & Berkoff, 2007). A first step in improving water supply services to farmers is analysing their response to the changes in the water tariffs that are required to maintain and/or improve irrigation services.

In this sense, the objective of this study is to analyse whether farmers in the Mitidja plain in northern Algeria are willing to pay an increased water tariff for the surface water they receive and to identify technical, social and economic factors that are related with their willingness to pay (WTP) for water. In addition, we estimated the water demand function for this irrigated area. The contribution of this study to the literature on irrigation water economics is mostly empirical. First, it estimated farmers' WTP for water in a Mediterranean developing country where this issue has received little attention. Second, contrarily to most studies estimating WTP for irrigation water, it takes into account the fact that alternative water resources may be available. Third, while most studies obtain a single WTP value for irrigation water, a water demand function was elicited. Last, it identified specific factors related to water management and governance in the area that directly affect WTP for surface water, and that are common to other irrigated areas both in Algeria and other Mediterranean countries. The results obtained are relevant for the analysis and design of water management policies (water pricing, investments in infrastructures, etc.).

## Material and methods

### The area of study

The plain of Mitidja is a coastal plain located in the north of Algeria, west from the city of Alger. It has an area of about 1450 km$^2$, with a length of 100 km and a width that ranges from 5 to 20 km. It is bounded by the River Nador on the west and the River Boudouaou on the East and bordered by two elevated areas: the Algerian Sahel in the North and the Bledéen Atlas in the South. Its Mediterranean climate is ideal for horticultural production and its soils are considered to be the most fertile in Algeria (Laoubi & Yamao, 2009a). Irrigation has consequently been a traditional activity in the area. The agricultural production of the Mitidja plain is mostly consumed within the country, providing most of the fruits and vegetables consumed in the Algiers region, whose population exceeds 4 million inhabitants (Imache, 2008).

Most agricultural land in the Mitidja plain belongs to the state but is cultivated by farmers holding land use rights in the form of collective farms (*Exploitation Agricole Collectif*, EAC) and individual farms (*Exploitation Agricole Individuelle*, EAI). These comprise between 3 and 20 farmers per farm, with sizes ranging between 10 and 50 ha (Imache *et al.*, 2009). About 86% of farms in the Mitidja are either EACs or EAIs (Messahel & Benhafid, 2007).

Irrigation in the Mitidja plain is divided into two large areas. First, the East Mitidja perimeter, located close to the city of Alger, suffers an accelerated process of land fragmentation and urbanization at the expense of farmland. On the other hand, the West Mitidja perimeter, located in the Western extreme of the Mitidja plain, is still an eminently agricultural area. The latter perimeter is organised in three different irrigation districts: a) the *Sahel Algerois* perimeter, located in Tipaza province, which started functioning in 2005 with an area of 2,888 ha; b) the *West Mitidja I* irrigated perimeter, located in the Blida province, which started functioning in 1989 with an area of 8,600 ha; and c) the *West Mitidja II* perimeter, which is the area selected for our study.

The West Mitidja II irrigation district started functioning in 2004 and covers an area of 15,600 ha, shared between the *Tipaza* province (14,400 ha) and the *Bilda* province (1,200 ha). It was selected as our study area because it is relatively modern, and thus its water distribution infrastructures are not significantly deteriorated yet. In addition, its socioeconomic characteristics and problems are representative of those of many of the public irrigated areas in Algeria. The irrigation district is divided in seven sectors (Table 1). The three first sectors receive pressurised water from ONID while the rest do not. All the sectors are served from the Bouromi dam, located south from the irrigated area, except sector C that is served from Boukerden dam, located west from the district. The water tariff paid by farmers is binomial, with a fixed rate of 400 Algerian Dinars (DA) per hectare (3.4 €/ha·year) and a volumetric component of 2.5 DA/m$^3$ (0,0212 €/m$^3$). According to the data provided by ONID, the average water cost during 2014 and 2015 was 4.53 DA/m$^3$ (0.0384 €/m$^3$), that is, 78.5% greater than the average water tariff in the area.

## Methodological approach

A major core of research in the economic valuation of water use in agriculture uses farm programming models that simulate crop and water use decisions at the farm/regional level and compute the marginal value of water and inverse water demand functions. Despite its ample advantages, such approach does not allow to identify those technical, economic and social factors that influence the value of water, one of the objectives of this study. For such reason, we have opted to use stated preferences methods, and more specifically contingent valuation (CV), in order to, in addition to estimating farmers' WTP for surface water, identifying the relevant variables behind the value of water.

State preference methods, such as CV, conjoint analysis and choice experiments, are been widely used to estimate the economic value of environmental goods and environmental improvement projects (Louviere *et al.*, 2000; Haab & McConnell, 2002). Stated preference

**Table 1.** Main characteristics of the seven sectors of West Mitidja II irrigation district.

| Sectors | Irrigable area (ha) | Irrigated area (ha) | Pressurised irrigation | Dam serving the sector |
|---|---|---|---|---|
| A | 2,450 | 2,250 | Yes | Bouromi |
| B | 2,330 | 1,983 | | |
| C | 3,020 | 2,389 | | Boukerden |
| D | 3,620 | 3,130 | No | Bouromi |
| E | 1,750 | 1,470 | | |
| F | 650 | 547 | | |
| G | 1,780 | 1,632 | | |
| Total | 15,600 | 13,401 | | |

*Source*: Own elaboration from data for 2014 provided by ONID.

methods, also called direct valuation methods or nonmarket valuation methods, were developed to value environmental goods and services that are not traded in real markets. Their objective is to obtain a reliable economic value for the provision of a non-marketed good or service (Mitchell & Carson, 1989).

Nonmarket valuation methods are based in the theory of utility maximisation of consumers and allow to monetarily measure the individuals' preferences for a change in the quantity or quality of an environmental good or service (Louviere *et al.*, 2000; Haab & McConnell, 2002). An individual's preference is measured as his/her willingness to pay (WTP), or alternatively his/her willingness to accept a compensation (WTA), for such change, which is a measure of its impact on the individual's welfare (Mitchell & Carson, 1989). The aggregation of individual WTPs over all the affected population thus provides an estimate of the impact of the valued change on the population's welfare (total economic value).

The WTP is elicited using a survey among a representative sample of the population affected by the change in the provision of the good or service. The respondents are faced with a hypothetical market setting (scenario) that includes a definition of the change in the provision of the good or service, the measures (project) that will be implemented to provide such change and how the payment/s for such change would be done (payment vehicle). Then the survey respondents are asked for the maximum amount of money that they are willing to pay for the proposed good, but are not bound to pay such amount. The design of the survey is the most critical point in the valuation process (Haab & McConnell, 2002). Mitchell & Carson (1989) present a detailed explanation of how CV surveys should be designed to provide plausible valuation scenarios and obtain reliable answers.

CV, as other stated preferences methods, can be used to obtain both use values (direct, indirect and option use values) and non-use values of water resources. Most studies using state preference methods to value water resources focus on domestic and environmental uses. In the case of irrigation water, some authors estimate farmer's WTP for an improvement in the water supply service and/or the level of water supply reliability (Chebil *et al.*, 2007; Rigby *et al.*, 2010; Mesa-Jurado *et al.*, 2012; Alhassan *et al.*, 2013; Martín-Ortega *et al.*, 2015), while other estimate farmers' WTP for using non-conventional water resources, such as reclaimed or desalinised water (Weldesilassie *et al.*, 2009; Bakopoulou *et al.*, 2010). Last, other authors have used CV techniques to estimate WTP for the quantity of irrigation water used (Garrido *et al.*, 1996; Mallios & Latinopoulos, 2001; Calatrava & Sayadi, 2005; Chandrasekaran *et al.*, 2009; Rigby *et al.*, 2010; Storm *et al.*, 2011; Benmihoub & Bedrani, 2012; Giannoccaro *et al.*, 2016).

In this study, CV was used to analyse whether farmers in the area of study (the affected population) were willing to pay an increased water tariff for the surface water they receive. A problem when asking farmers for their WTP for surface water arise from the fact that it is unlikely that many respondents accept to pay more for the water they currently receive. To address this problem and avoid overestimating the actual WTP, farmers were informed in plain language about the situation of the infrastructures of the irrigated area, the risk of deterioration of the water supply service if proper maintenance is not done and the need for additional funds to cover the operation and maintenance (O&M) costs of the district. The "good" to be valued in the hypothetical market scenario was not an improvement of the water supply service but maintaining it in its current level. The payment vehicle proposed was an increase in the water tariff. Farmers were then asked for their WTP for an increased water tariff in order to prevent the deterioration of the water supply service and maintain it as it is now in terms of quantity, quality and reliability.

## Factors related with the WTP for irrigation water

Apart from providing the economic value of water, CV, as all nonmarket valuation techniques, can be also used to infer its relationship to other variables (economic, personal, demographic, policy, etc.). The literature shows that the variables that are related with farmers' WTP for irrigation water and/or improvements in the irrigation water supply service depend on each specific case study. However, there are some factors that appear more frequently to be related with such WTP than others. A major group of factors are those related with the farm's characteristics, such as cropping patterns, crop yields and profitability, crop water needs, farm size, farm location, farm ownership, etc. For example, WTP for water is found in many studies to be greater for more productive and profitable crops (Garrido *et al.*, 1996; Calatrava & Sayadi, 2005; Chebil *et al.*, 2007; Weldesilassie *et al.*, 2009; Storm *et al.*, 2011; Benmihoub & Bedrani, 2012; Giannoccaro *et al.*, 2016). Depending on the specific area of study, farm size is related to WTP either positively (Garrido *et al.*, 1996; Calatrava & Sayadi, 2005; Chebil *et al.*, 2007; Rigby *et al.*, 2010; Benmihoub & Bedrani, 2012) or negatively (Chandrasekaran *et al.*, 2009; Bakopoulou *et al.*, 2010; Mesa-Jurado *et al.*, 2012).

A second group includes variables related with irrigation water and its attributes: water quality, water availability/scarcity, access to alternative water sources, supply reliability, etc. The level of water availability (scarcity) is expected to be negatively (positively) related with WTP for water (Mallios & Latinopoulos, 2001; Chandrasekaran *et al.*, 2009; Bakopoulou *et al.*, 2010; Storm *et al.*, 2011; Mesa-Jurado *et al.*, 2012; Giannoccaro *et al.*, 2016). Similarly, a higher level of supply reliability (Rigby *et al.*, 2010; Mesa-Jurado *et al.*, 2012), a better perception of the quality of the water service (Benmihoub & Bedrani, 2012) and the access to several sources of water (Mallios & Latinopoulos, 2001; Storm *et al.*, 2011) are likely to increase WTP. Better water quality is also likely to increase WTP (Weldesilassie *et al.*, 2009; Bakopoulou *et al.*, 2010).

Last, another major group include socio-economic factors. Variables such as income, famer's age, educational level, experience, agricultural training, risk attitudes, use of family labour, family size, have often proved to be good predictors of WTP for water and/or improvements in water supply. A higher educational level (Mallios & Latinopoulos, 2001; Weldesilassie *et al.*, 2009; Bakopoulou *et al.*, 2010), agricultural training (Calatrava & Sayadi, 2005; Mesa-Jurado *et al.*, 2012) and experience with irrigation (Weldesilassie *et al.*, 2009) are frequently positively related with WTP. Contrarily, farmer's age has been found to negatively influence WTP (Storm *et al.*, 2011; Mesa-Jurado *et al.*, 2012), similarly to the use of family labour (Chandrasekaran *et al.*, 2009). Last, WTP for water has been found to increase with household size (Mallios & Latinopoulos, 2001; Weldesilassie *et al.*, 2009; Mesa-Jurado *et al.*, 2012).

## Data source

The data used in this analysis come from a survey administered in 2015 to 112 randomly selected farmers from the West Mitidja II irrigated area. Previous to the survey design, we compiled existing secondary data and literature on the area of study and conducted an exploratory survey that consisted of a series of interviews with representatives from several relevant institutions. ONID provided technical and economic data for the irrigated perimeters in the area of study, while the agricultural services of the Tipaza province (DSA) provided some farms statistics for the area of study. All this information enabled us to design the questionnaire and the sampling.

The survey was designed based on the reviewed literature on WTP for irrigation water and/or improvements in the irrigation water supply service, taking into account the specific socio-economic characteristics of irrigated agriculture in the area of study. The questionnaire asked farmers about: a) farm characteristics and economic structure (size, cropping patterns, type of labour used, land ownership and tenancy issues, exposure to risk, etc.); b) water consumption, price and quality; c) adoption of irrigation technologies and water management decisions; d) opinions about water management at the irrigated perimeter level; e) questions related to the economic valuation of water; and f) farmer's characteristics (age, educational level, income, agricultural training and experience, sources of technical information and advice, dedication to agriculture, etc.).

The surveyed farmers were selected by stratified random sampling using a random walk procedure. The sample was stratified based on the type of farm (public collective, public individual and private), the type of crops cultivated and the sector of the irrigated area where farms are located (Table 2). Stratification was done by proportional numerical affixation in all cases. We could not consider the farm size because we did not have the statistical data required to do it.

Farmers were interviewed face-to-face in their own farm. The answers to the survey were revised to check their validity and codified. Farmers belonging to a collective farm (EAC) were considered as having an independent farm. All survey data collected was revised and validated. We interviewed 120 farmers that provided a total of 112 valid questionnaires, because 8 farmers left many questions unanswered and/or provided contradictory answers. The sampling standard error was 8.6% for the estimation of intermediate proportions and 3.8% for the estimation of extreme proportions.

## Questions related to the economic value of surface water

A major issue in the design of CV questionnaires is the choice of the format of the WTP elicitation question (open-ended, bidding games, payment cards and close-ended or dichotomous choice). Each format has advantages and disadvantages and there is not a clear consent in the literature about which is the best format (Carson *et al.*, 2001), although dichotomous choice is the most used approach, mostly because the other methods have been proved to suffer from incentive compatibility problems (Haab & McConnell, 2002). Nevertheless, Loomis (1990) points at the similar reliability of WTP estimates obtained using both dichotomous choice and open-ended questions.

In the specific case of irrigation water, half of the reviewed studies use different versions of the dichotomous choice format (Garrido *et al.*, 1996; Mallios & Latinopoulos, 2001; Chebil *et al.*, 2007; Chandrasekaran *et al.*, 2009; Weldesilassie *et al.*,

**Table 2.** Sample stratification based on farm status, district's sector and type of crops

| Stratification variable | | Proportion in the population | Proportion in the sample |
|---|---|---|---|
| Farm status | Collective farm | 0.750 | 0.750 |
| | Individual farm | 0.065 | 0.067 |
| | Private farm | 0.185 | 0.183 |
| | Total | 1.000 | 1.000 |
| Sector of the district | A | 0.155 | 0.158 |
| | B | 0.131 | 0.133 |
| | C | 0.070 | 0.067 |
| | D | 0.394 | 0.392 |
| | E | 0.144 | 0.142 |
| | F | 0.032 | 0.033 |
| | G | 0.074 | 0.075 |
| | Total | 1.000 | 1.000 |
| Type of crop | Citrus | 0.314 | 0.345 |
| | Horticulture | 0.369 | 0.418 |
| | Fruit tree | 0.184 | 0.133 |
| | Cereals | 0.133 | 0.104 |
| | Total | 1.000 | 1.000 |

*Source*: Own elaboration from the sample and data for 2014 provided by ONID.

2009; Bakopoulou *et al.*, 2010), while other use open-ended questions (Calatrava & Sayadi, 2005; Storm *et al.*, 2011) or payment cards (Mesa-Jurado *et al.*, 2012; Alhassan *et al.*, 2013), or choice modelling (Rigby *et al.*, 2010).

Although the open-ended format is recommended in cases where the respondents have familiarity with paying for the good being valued (Mitchell & Carson, 1989), as it is the case with irrigators, we finally used the discrete choice format because, during the pre-test of the questionnaire, farmers were reluctant to give an answer without some price value being proposed to them. In fact, the open-ended usually provides a larger number of protest zeros (Carson *et al.*, 2001).

More specifically, to survey farmers about their WTP for irrigation surface water, we used a dichotomous choice CV format (Hanemann, 1984; Hanemann *et al.*, 1991) but proposing farmers several increasing bid prices. As previously commented, farmers were asked about their WTP for an increased tariff for surface water, contingent on the current water supply service being maintained as it is now in terms of quantity, quality and reliability. The WTP question was stated as "You have been informed that the water tariff that you currently pay does not cover the operating and maintenance costs of the irrigated perimeter. ONID is considering the possibility of increasing the water tariff in order to maintain the water supply service in the current conditions. Would you be willing to pay X DA/m$^3$ for the same amount of water that you currently receive from ONID?" We first asked farmers if they were willing to pay 3 DA/m$^3$, a price that is slightly higher than the one they are currently paying. In case of a positive answer, we repeated the question for 4 DA/m$^3$, 5 DA/m$^3$ (twice the current tariff) and so on, until a negative answer was given. Bid prices were proposed on a descending order to half of the surveyed farmers.

To elicit farmers water demand curve, we used a similar method to Garrido *et al.* (1996), who asked farmers in the Spanish Guadalquivir basin what would be their response to increases in the price of water they paid, in terms of alternative such as abandoning agriculture, reducing water use, changing cropping patterns, etc. In our case, we alternatively proposed farmers a hypothetical situation in which they could use as much water as they like without any restriction, and ask them how much water they would use if the water price was lower, equal and higher than the current one. More specifically, we proposed the following prices: 0, 1, 2, 2.5, 3, 4, 5, 7.5 and 10 DA/m$^3$.

## Logit model specification and calculation of WTP

The surveyed farmer's decision to accept each proposed price bid was analysed by estimating a binomial logit model, as proposed by Hanemann (1984). We also tested a probit specification but it provided similar results with a lower goodness of fit.

The dependent variable in the binomial Logit model is the probability of the observed binary variable *Y* taking the value 1, where *Y*=1 means that the farmer has accepted the proposed price bid and *Y*=0 that the farmer has not accepted it. The Logit function is a cumulative density function that follows a logistic distribution and is defined as the probability of *Y*=1:

$$P(Y=1) = \int_{-\infty}^{\beta' x} \phi(t)dt = \Phi(\beta' x) = \frac{1}{1+e^{-\beta' x}} = 1 - \frac{1}{1+e^{\beta' x}} \quad [1]$$

where $\phi$ and $\Phi$ are the logistic probability density function and the logistic cumulative density function, respectively; $x$ is a matrix of the variables that can be related to the acceptance of the proposed price bid; and $\beta'$ is a vector of coefficients of the variables in $x$, such as:

$$\beta' x = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_N x_N \quad [2]$$

The model was estimated by maximum-likelihood. The estimated model's coefficients, $\beta$, can be used to determine the probability of the binary dependent variable being equal to one (*i.e.* the farmer accepting the proposed price bid) given specific values of the independent variables $x$ (Greene, 2007). The $\beta$ of each explanatory variable is not equal to the marginal effect (*ME*) of that explanatory variable, which measures the percentage change in the likelihood of the farmer accepting the proposed price bid due to a unitary change in that variable. The *ME* for the explanatory dummy variables were measured as the difference between the value of the prediction when the variable equals 1 and when it equals 0, where all other variables are unchanged at their respective mean values (Greene, 2007). For continuous explanatory variables, the marginal effects were calculated at the mean values of the other variables as $ME = \phi(\hat{\beta} x)\hat{\beta}$ (Maddala, 1983). The significance of both the regression coefficients and the *ME* was tested using the Student's t statistic. The goodness of fit of the estimated model was measured using several pseudo-$R^2$ statistics (McFadden, Cox & Snell and Nagelkerke) and the classification tables, which represent the percentage of correct predictions that the model provides for the data in the sample (Greene, 2007).

The independent variables included in the estimated Logit model are shown in Table 3. In addition to the variables representing the farm and farmer's characteristics, we included the different water price bids proposed to the farmers as an explanatory variable. This allowed us to obtain an estimate of the farmers' mean WTP for irrigation water, following Hanemann (1989) and Loomis *et al.* (1997, 2000), as:

$$Mean\ WTP = -\frac{\ln\left(1 + e^{\beta_0 + \beta_2 \bar{x}_2 + \cdots + \beta_N \bar{x}_N}\right)}{\beta_1} \quad [3]$$

where $\beta_1$ is the estimated coefficient of the proposed bid variable $x_1$. Although we will only use the mean WTP in the analysis of our results, median WTP was calculated as in Loomis *et al.* (1997) as:

$$Median\ WTP = -\frac{\beta_0 + \beta_2 \bar{x}_2 + \cdots + \beta_N \bar{x}_N}{\beta_1} \quad [4]$$

As already commented, the marginal effect of each continuous explanatory variable $x_i$ on the probability of accepting a given price bid was calculated as (Maddala, 1983):

$$\frac{\partial Prob(Y=1)}{\partial x_i} = \beta_i \phi(\beta_i \bar{x}_i) = \beta_i \frac{e^{\beta_0 + \beta_1 \bar{x}_1 + \beta_2 \bar{x}_2 + \cdots + \beta_N \bar{x}_N}}{[1 + e^{\beta_0 + \beta_1 \bar{x}_1 + \beta_2 \bar{x}_2 + \cdots + \beta_N \bar{x}_N}]^2} \quad [5]$$

Finally, following Loomis (1987) and Cameron (1988), the marginal effect of each explanatory variable $x_i$ on the WTP was calculated as in Thorvaldson *et al.* (2010) as:

$$\frac{\partial WTP}{\partial x_i} = \frac{\beta_i}{|\beta_1|} \quad [6]$$

In addition to estimating farmers' WTP for surface water, we identified from the model those technical, social and economic factors that are related with it.

# Results

## General characteristics of farms and farmers in the sample

The size of farms in the sample ranged between 1 and 200 ha, with an average of 14.64 ha. The majority of farms (74.1%) were public collective farms (EAC) owned by the Algerian Government and managed collectively. Each EAC farm is cultivated by a group of farmers that share the land equally but in practice cultivate their plot individually taking crop decisions independently (although they usually cultivate similar crops). In the sample, the number of EAC members ranged between 3 and 9 with an average of 6. Public individual farms (EAI), accounting for 5.4% of the sample, differ from EAC in that a single farmer cultivates them. EAC members and EAI farmers cannot sell or rent the land. Last, privately owned farms accounted for 20.5% of farms in the sample. One out of five farmers in the sample rented the land he cultivates, despite the prohibition of renting public lands. In practice, informal renting of EAC and EAI land is a common practice in the area (Imache *et al.*, 2009).

The main crop orientations in the area were citrus and horticulture. Citrus were cultivated by 55.4% of surveyed farmers, while 48.2% cultivated vegetables,

**Table 3.** Description of variables used in the analysis

| Variable | Definition | Mean / Proportion | Standard deviation |
|---|---|---|---|
| BID | Bid price proposed (DA/m$^3$) | - | |
| FARMTYPE | Farm status: | | |
| | 1: public collective farm (FARM TYPE-EAC) | 0.741 | |
| | 2: public individual farm (FARM TYPE-EAI) | 0.054 | |
| | 3: private farm (FARM TYPE-PRIVATE) | 0.205 | |
| TENANT | Farmer rents the land he cultivates (1=Yes, 0 = No) | 0.214 | |
| FARMSIZE | Total agricultural area (ha) | 14.64 | 26.80 |
| CROP | Proportion of farm area devoted to different crops | | |
| | 0: Non-irrigated crops | 0.186 | |
| | 1: percentage of citrus (CITRUS) | 0.339 | |
| | 2: percentage of fruit trees (ROSACEAE) | 0.167 | |
| | 3: percentage of irrigated cereals (CEREALS) | 0.053 | |
| | 4: percentage of horticultural crops (HORTICULTURE) | 0.255 | |
| FAMLYLABOUR | Percentage of family labour over total farm labour | 0.171 | 25.54 |
| GROUNDWATER | Access to groundwater resources (1= Yes, 0= No) | 0.670 | |
| WATERUSE | Annual water consumption per hectare (m$^3$/ha) | 4572.94 | 1640.49 |
| IRRITECH | Irrigation technologies used: | | |
| | 1: furrow irrigation (FURROW) | 0.580 | |
| | 2: sprinkler irrigation (SPRINKLER) | 0.366 | |
| | 3: drip irrigation (DRIP) | 0.420 | |
| AGE | Age of the farmer (years) | 48 | 12.26 |
| EDUCATION | The education level of respondents: | | |
| | 0: Illiterate | 0.036 | |
| | 1: Elementary school EDUCATION: PRIMARY | 0.366 | |
| | 2: Secondary school EDUCATION: SECONDARY | 0.188 | |
| | 3: High school EDUCATION: BACHELOR | 0.258 | |
| | 4: University studies EDUCATION: UNIVERSITY | 0.152 | |
| COURSES | Attendance to farming training courses (1=Yes, 0=No) | 0.482 | |
| DEDICATION | Dedication measured as proportion of family revenue coming from farming: | | |
| | Sample average proportion: | 0.889 | |
| | Per strata: | | |
| | 1: Total (≥80%) | 0.759 | |
| | 2: Main (50-80%) | 0.187 | |
| | 3: Secondary (20-50%) | 0.054 | |
| | 4: Marginal (≤20%) | 0.000 | |
| REVENUEPC | Family Revenue (DA per family member) | 19088.31 | 19294.17 |
| COOPERATIVE | Farmer belongs to an agricultural cooperative (1=Yes, 0=No) | 0.143 | |
| INNOVATIVE | Farmer classified as innovative (1=Yes, 0=No), based on his answers to a question asking how he decides to adopt new practices and technologies. | 0.420 | |
| RISK | Farmer`s assessment of his activity's risk exposure (from 0 to 100 %) | 56.46 | 21.38 |

*Source*: Own elaboration. DA: Algerian Dinar.

35.7% cultivated other mild-temperate climate fruit trees, and 9.8% irrigated cereals. On the other hand, 33.9% of farmers cultivated non-irrigated crops, mostly cereals. In Table 3, we show the average proportion of farm area cultivated with each crop type, as it is the variable used in the WTP model.

Farmer's age ranged between 20 and 80 years with an average of 48 years (with little variability). All of them were male. Regarding their educational level, 41% of farmers held either a high school (Baccalaureate) or a university degree, while only 3.6% were illiterate. Nearly 95% of farmers had agriculture as the main source of income for their family.

## Water management

Regarding water management, 42% of farms were drip irrigated, while 36.6% used sprinklers and 58.0% were irrigated by flooding the land. In addition to surface water, 67% of the surveyed farmers had access to groundwater resources from wells and water drilling, in most cases of an illegal nature (Imache *et al.*, 2009). As we will later see, this is a relevant factor in our analysis.

The surveyed farmers positively valued the water supply service that they receive from ONID. A majority of farmers was satisfied with the quality of surface water (70.7%) and with the district's water supply management (72.6%). Despite the frequent complains related to the delay and irregularity of timetables of water distribution and the lack of a more flexible on-demand supply, the average rating of this aspect was 69.7% (measured on a 0 to 100% rating scale).

## Willingness to pay for surface water

Before posing the WTP questions, we asked farmers about their perception of the level of water supply cost recovery achieved through the water tariffs they pay. A vast majority (82%) thought that the tariffs they pay cover, or even surpass, water supply costs. Then we asked them about their reaction to an increase in the water tariff: 50% answered that would continue to irrigate the same, while 37.5% would claim for an improvement of water supply in exchange and 12.5% answered that they would stop using surface water.

Table 4 presents the proportion of positive answers to each proposed price bid. None of the farmers refused to answer the WTP question and there were not protest responses. While 21.4% of farmers were not willing to pay more than they currently pay for surface water, 25 % of farmers would accept to pay twice as they currently do (5 DA/m$^3$). All farmers refused to pay more than 5 DA/m$^3$, which they considered a very expensive price. Table 5 shows the reasons given by the respondents when they did not accept to pay each proposed bid price. The main reason for farmers not accepting a given price was considering it to be too high.

Results for the estimated Logit model are shown in Table 6 that presents the estimated model coefficients, the proportions of correct classification and the marginal effects and elasticities of the explanatory variables. The likelihood ratio test indicates that the estimated model was significant ($p$=0.0000), whereas the high values of the pseudo-$R^2$s and the high percentage of sampled cases that were correctly classified (75.9%) indicate a very good fit and a high discriminant performance (Table 6).

From the model results we calculated the average farmers' WTP for surface water following Hanemann (1989) and Loomis *et al.* (1997, 2000). Average WTP for surface water was 4.11 DA/m$^3$, which is a 64% increase in the current water tariff. Average WTP (4.1113 DA/m$^3$) was almost identical to the median WTP (4.1096 DA/m$^3$).

**Table 4.** Proportion of farmers accepting each proposed water price bid

| Price bids (DA/m$^3$) | Increase over current price (DA/m$^3$) | Positive answers (number) | Positive answers (%) |
|---|---|---|---|
| 3 | 0.5 | 88 | 78.6 |
| 4 | 1.5 | 61 | 54.5 |
| 5 | 2.5 | 28 | 25.0 |
| > 5 | >2.5 | 0 | 0 |

*Source*: Own elaboration. DA: Algerian Dinar.

**Table 5.** Reasons for not accepting each proposed price bid (proportion of total respondents)

| Reason | Proposed bid price (DA/m$^3$) | | | |
|---|---|---|---|---|
| | 3 | 4 | 5 | >5 |
| The proposed water price is high for me | 13.3 | 29.5 | 55.4 | 100.0 |
| At this price, I prefer to use groundwater | 4.5 | 12.5 | 15.2 | 0.0 |
| The water distribution system is not good enough to pay this price | 2.7 | 3.5 | 4.4 | 0.0 |
| The water quality is not good enough to pay this price | 0.9 | 0.0 | 0.0 | 0.0 |
| TOTAL | 21.4 | 45.5 | 75.0 | 100.0 |

*Source*: Own elaboration. DA: Algerian Dinar.

Results in Table 6 show that the likelihood of a farmer willing to pay a certain proposed bid was greater when the farmer attends training courses to improve its farming skills (COURSES variable) and when the farmer is member of an agricultural cooperative (COOPERATIVE variable). In addition, the likelihood of a farmer willing to pay a certain proposed bid increased with the share of farm area devoted to horticultural and citrus crops (HORTICULTURE AND CITRUS).

On the contrary, the probability of a farmer willing to pay a given price bid decreased with the size of the water price bid (BID variable), with the age of the farmer (AGE variable) and with the perceived exposure to risk (RISK variable), and was smaller for farmers on collective public farms with respect to private farms and public individual farms (FARM TYPE variables) and when the farmer had access to water from a private or communal well (GRONDWATER variable). The other variables included in the model had no effect on WTP for surface water in the area of study.

All the variables that were significant in the dichotomous choice model had significant marginal effects and elasticities (Table 6). The marginal effects associated with the variables that represent the price bid proposed, the type of farm, the access to groundwater, the adhesion to an agricultural cooperative and the attendance to agricultural training courses were the greatest. The first three variables reduced the likelihood of accepting to pay a certain bid price by 24.3%, 23.4% and 14.9% respectively. On the contrary, the last two variables increased the likelihood of accepting to pay a certain bid price by 22.6% and 15.0% respectively. With the exception of

**Table 6.** Estimated binomial ordered Logit model of WTP for surface water

| Explanatory variable | Model Coefficient | Marginal effects | Elasticities |
|---|---|---|---|
| CONSTANT | 9.098 *** | - | - |
| BID | -1.455 *** | -0.243 *** | -3.013 *** |
| FARM TYPE: EAC | -1.399 ** | -0.234 ** | -0.520 * |
| FARM TYPE: PRIVATE | -1.342 | -0.125 | -0.065 |
| TENANT | -0.473 | -0.079 | -0.175 |
| FARMSIZE | 0.003 | 0.001 | 0.020 |
| CITRUS | 0.011 * | 0.002 * | 0.172 * |
| ROSACEAE | 0.008 | 0.001 | 0.067 |
| CEREALS | 0.009 | 0.002 | 0.020 |
| HORTICULTURE | 0.018 ** | 0.003 ** | 0.205 ** |
| FAMILYLABOUR | 0.0001 | 0.000 | 0.002 |
| GROUNDWATER | -0.874 ** | -0.149 ** | -0.302 ** |
| WATER USE | 0.0001 | -0.000 | -0.153 |
| SPRINKLER | 0.003 | 0.001 | 0.036 |
| DRIP | -0.005 | -0.001 | -0.063 |
| AGE | -0.031 * | -0.005 * | -0.709 * |
| EDUCATION: PRIMARY | -0.658 | -0.110 | -0.072 |
| EDUCATION: SECONDARY | -0.404 | -0.068 | -0.065 |
| EDUCATION: BACHELOR | -0.331 | -0.055 | -0.039 |
| EDUCATION: UNIVERSITY | -0.335 | -0.056 | -0.023 |
| COURSES | 0.899 *** | 0.150 *** | 0.185 *** |
| DEDICATION | 0.004 | 0.001 | 0.186 |
| REVENUEPC | -0.000 | -0.000 | -0.023 |
| COOPERATIVE | 1.350 *** | 0.226 *** | 0.064 *** |
| INNOVATIVE | 0.282 | 0.047 | 0.055 |
| RISK | -0.029 *** | -0.005 *** | -0.823 *** |
| Likelihood ratio | 338.86 *** | | |
| Pseudo-$R^2$ McFadden | 0.2710 | | |
| Pseudo-$R^2$ Cox & Snell | 0.313 | | |
| Pseudo-$R^2$ Nagelkerke | 0.417 | | |
| % of correct predictions | 75.9 | | |
| % of “0” correctly predicted | 74.7 | | |
| % of “1” correctly predicted | 77.0 | | |

*Source*: Own elaboration. * $p$<0.10; ** $p$<0.05; *** $p$<.01. Model predictions based on threshold c=0.5.

the bid price variable, the elasticities of the continuous variables in the model were small, showing that WTP was inelastic to changes in the area planted with horticultural and citrus crops, to the farmer’s age and to risk exposure (Table 6).

## Farmers’ surface water demand curve

Table 7 shows the proportion of surveyed farmers that would continue using surface water from the district for each proposed bid price under the hypothetical scenario of unrestricted water supply, as well as the average amount of water demanded and its coefficient of variation, while Figure 1 shows the average amount of water demanded for the different proposed water prices (presented as an inverse water demand curve) and its variability.

Farmers’ response to increased water charges was obviously to reduce water consumption. For the current water price (2.5 DA/$m^3$), average water demand was greater than current water consumption (6268 $m^3$/ha compared to 4573 $m^3$/ha). A slightly increased water price (3 DA/$m^3$) resulted in 15 farmers renouncing to use surface water but average water

**Table 7**. Proportion of farmers demanding water for each proposed water price bid

| Price bids (DA/m³) | Variation with respect to the current price (DA/m³) | Farmers using surface water | | Average water use (m³/ha) | Coefficient of variation |
|---|---|---|---|---|---|
| | | No. | % | | |
| 0.0 | -2.5 | 112 | 100 | 6821 | 0.43 |
| 1.0 | -1.5 | 112 | 100 | 6732 | 0.42 |
| 2.0 | -0.5 | 112 | 100 | 6429 | 0.35 |
| 2.5 | 0 | 112 | 100 | 6268 | 0.33 |
| 3 | +0.5 | 97 | 86.6 | 4926 | 0.59 |
| 4 | +2.5 | 82 | 73.2 | 3901 | 0.59 |
| 5 | +2.5 | 65 | 58.0 | 2348 | 1.02 |
| 7.5 | +5.0 | 24 | 21.4 | 629 | 1.98 |
| 10 | +7.5 | 13 | 11.3 | 299 | 2.94 |

*Source*: Own elaboration.

demand would still be greater than the current one. For a 100% increase in the current water price (5 DA/m$^3$), 58% of farmers would continue using surface water but average water demand would be nearly half of the current water consumption (2348 m$^3$/ha compared to 4573 m$^3$/ha). The decrease in the average water volume demanded accelerated for prices greater than 5 DA/m$^3$. Water demand turned to zero for an unidentified price above 10 DA/m$^3$. In addition, the volume of water demanded presented a significant level of variability, with the coefficient of variation increasing with the proposed water price. Such variability was caused by the existence of a small number of farmers growing horticultural crops and demanding water quantities quite above the average for the range of water prices proposed.

Figure 2 presents the arc elasticity of the water demand curve. It can be seen how the price-elasticity of surface water demand increased with the water price bid proposed to farmers. The demand was inelastic for water prices below 4.5 DA/m$^3$ and elastic for prices greater than 4.5 DA/m$^3$.

## Discussion

This study has estimated farmers' WTP for surface water in the West Mitidja irrigated area in northern Algeria using CV techniques. It also identified which technical, social and economic variables are related with such WTP. This is a relatively modern irrigation district, whose water distribution infrastructures are in risk of deterioration in the future, as the water tariff paid by farmers does not cover the operation and maintenance costs. Although the Algerian Government subsidises ONID, the public enterprise in charge of

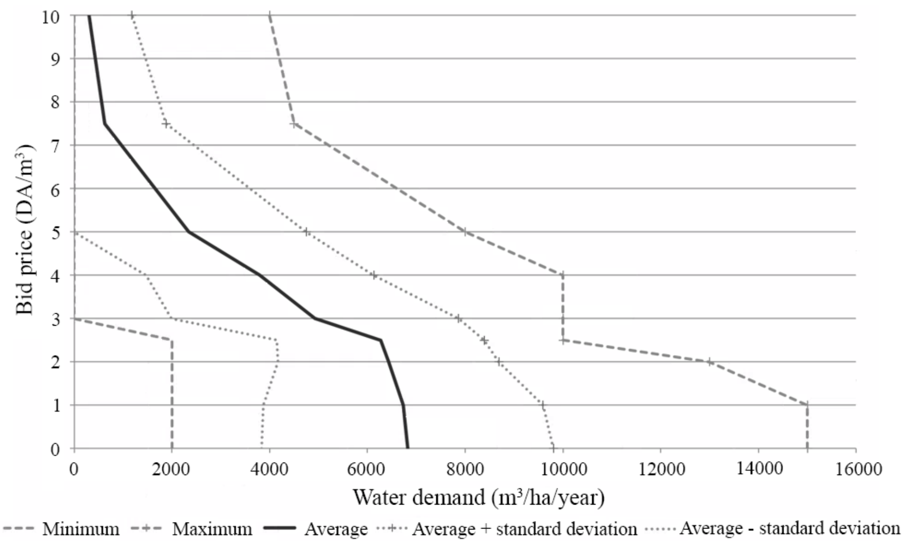


**Figure 1.** Water volume per hectare demanded by the surveyed farmers for different water price bids. *Source*: Own elaboration

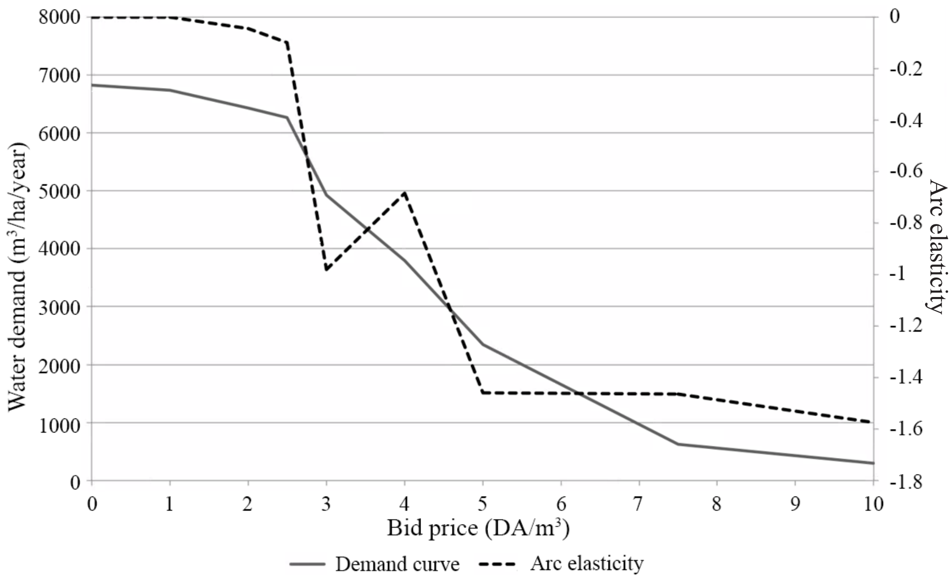


**Figure 2.** Arc elasticity of the water demand curve obtained from the survey to farmers. *Source*: Own elaboration.

managing public irrigated areas, such subsidies are insufficient to guarantee the correct maintenance of the districts' infrastructures.

Our results show that nearly 80% of the surveyed farmers were willing to pay an increased price for the surface water that they use in order to maintain the water supply service as it currently is in terms of quantity, quality and reliability. Average WTP for surface water, at the current level of water use, was 4.11 DA /m$^3$ (equivalent to 0.0349 €/m$^3$), what represents a 64% increase with respect to the current water tariff. Even assuming some strategic behaviour in the farmer's answers, these results suggests that there is some margin to increase water tariffs and thus the financial resources of the irrigated area, allowing to finance investments for the maintenance of its water distribution infrastructures. However, such value was lower than average operation and maintenance costs of the irrigated perimeter (equivalent to 4.53 DA/m$^3$). Therefore, a water tariff equivalent to the average WTP would only cover 90% of the irrigation district's operation and maintenance costs. In addition, according to the water demand curve obtained from farmers' responses, should a water tariff were set to cover the average unitary district's O&M costs (4.53 DA/m$^3$), average surface water demand would be reduced to about 3078 m$^3$/ha (one third from the current demand) and the collected proceeds would likely be not enough to cover all O&M costs. Consequently, there is a need to act in order to increase farmers WTP.

Farmer`s WTP is affected by several variables identified in the estimated logit model. The interpretation of the logit model's estimated coefficients is more or less straightforward depending on the variable whose effect we look at. As expected, farmers' WTP for surface water decreased with the proposed bid price for surface water, which was the most relevant variable in the model. The marginal effect of the bid price variable was very high: on average, each additional increase of 1 DA/m$^3$ in the bid price reduced the probability of the farmer accepting the bid by 24.3%. In fact, none of the surveyed farmers were willing to pay more than twice the current water price. Despite this, the price elasticity of water demand was found to be inelastic for prices below 4.5 DA/m$^3$. This is consistent with most studies on irrigation water pricing that conclude that water demand is very inelastic in the short term, at least for low water tariffs, reduced water availability or more profitable crops (see, for example, Scheierling *et al.*, 2006 and Giannocaro *et al.*, 2010).

Similarly, access to groundwater reduced the probability of accepting to pay a specific price for surface water. Farmers that had access to an alternative source of water would be less willing to pay a higher price for surface water from the irrigation district. The option to rely on groundwater may be one factor behind the price elasticity of the demand for surface water in the area. However, the access to groundwater reduced but did not offset the demand for surface water. While groundwater in the area has better quality than water from the dams, it is also more expensive for farmers. In addition, for many farmers, groundwater availability is not enough to irrigate their entire plot, especially in more water-demanding crops such as citrus crops, so many farmers cannot renounce completely to using surface water.

Another expected result relates to cropping patterns: farmers growing more profitable crops, such as horticultural and citrus crops, were likely to have a greater WTP for surface water. In addition to its profitability, citrus have high water requirements. Citrus farmers usually rely on groundwater to secure their supply, but in most cases the existing wells are not able to provide enough water to irrigate the entire plot. Thus, surface water is essential to meet these crops' high water needs and, as a result, citrus farmers were willing to pay more for it.

A key result relates to the type of farm in relation with the collective status of some farms. The model's results show that farmers belonging to a collective farm were less willing to pay for surface water. Although farmers on collective farms (EAC) cultivate their land plot individually, they share a single water concession and water-metering device, what creates problems related with the payment of the water tariff to ONID. For example, some EAC farmers lease their plots annually to private agricultural operators that sometimes leave unpaid water bills behind them after harvesting. The other members in the EAC are forced to pay these bills for water they have not consumed before the start of the new irrigation campaign, as ONID does not distribute water to farms with debts from the previous year. Consequently, EAC farmers are demanding individual metering devices. We can hypothesize that solving this problem could result in a greater WTP for water of EAC farmers (three out of four farmers in the area of study). If we assume that installing individual metering devices would totally eliminate the negative marginal effect of this variable on the mean WTP (-0.96 DA/m$^3$), the latter would increase from 4,11 to 5.07 DA/m$^3$, above average O&M costs.

Turning to the effect of the farmer's personal characteristics on WTP, another interesting result relates to farmers' educational level and permanent agricultural training. While the former was not significantly related with WTP for irrigation water, the attendance to courses to improve his farming knowledge and skills increased the likelihood of a farmer accepting a higher bid (by 15%). Similarly, farmers belonging to an agricultural cooperative were 22.6% more likely to accept a higher price bid for surface water. A possible interpretation of these results could be that farmers that improve their training and belong to a cooperative may be getting a higher economic return from their farming activity and thus have a greater WTP for surface water.

Probably related to this last result is the effect of the perception that the farmer has about the level of riskiness of his agricultural activity. The more the farmer felt his profits were at risk the less he was willing to pay for surface water. The perceived risk exposure had a small marginal effect but a relatively high, albeit inelastic, elasticity. Last, our results showed that older farmers were willing to pay less for surface water. Older farmers seem to have a more traditional view of water as a divine gift one should not pay for, what may reduce their WTP.

The other variables included in the model, such as the farmer being a lessee, farm size, irrigation technology, use of family labour, dedication to agriculture, etc., have no effect on WTP for surface water in the area of study. The most relevant result in this sense, in the non-existence of a scale effect in WTP, as farm size one of the most frequently significant variables in the literature, although with different signs depending on each case study.

As shown above, farmer`s WTP was mostly affected by the collective nature of the farm, the cropping patterns, the access to alternative groundwater resources, whether the farmers attended permanent agricultural training activities and belonged to an agricultural cooperative, and their perception about the level of risk exposure of their farming activity. In general, these results were coherent and consistent with those from previous studies that analyse the WTP for irrigation water in other countries (see section on the factors related with the WTP for irrigation water). Acting on some of these factors could increase WTP for surface water above average O&M costs.

Although they fall out of the scope of this paper, there are some issues that deserve consideration and further research for improving water management in the area. Probably, the most relevant one is the design of an adequate water tariff based on the estimated farmers' water demand and the irrigated area's water supply costs. Considering that O&M costs are a combination of both fixed and variable costs, not only water charges should be increased to allow for the recovery of O&M costs, but an adequate binomial pricing structure should be set to balance both the fixed and variable proceeds collected through the water tariff and ensure the financial sustainability of the area. Unfortunately, the available data on O&M costs for the West Mitidja irrigated area does not distinguish between fixed and variable costs and it has not been possible to estimate a cost recovery curve to properly address this issue.

Directly related with the above is the issue of the policy objectives pursued. In this study, we have analysed farmers' WTP with an eye on increasing water charges to achieve the objective of collecting enough proceeds to cover the irrigated area's O&M costs. Achieving cost recovery has the advantage of providing financial stability to the irrigated areas, but does not necessarily contribute to other policy objectives, such as achieving an efficient or equitable water allocation, increasing water use efficiency or increasing water security. Of special relevance is water security, a critical issue for rural areas in developing countries. Water insecurity affects farmers' income stability but also threatens the viability of water policies and of irrigation itself as an economic activity (OECD, 2015). An interesting line of research would address how the design of water tariffs in the area could balance the trade-offs between different policy objectives.

Nevertheless, even if water tariffs are not optimally designed to reach other policy objectives, increasing water charges has additional advantages to just the budgetary equilibrium of irrigated perimeters. If infrastructures are not properly maintained and deteriorate, water losses in the distribution network would increase, reducing the reliability of water supply and the water volumes delivered to farmers. This would result in less water security, water use efficiency, economic efficiency and resilience to face water supply variability and uncertainty. In addition, if the surface water supply deteriorates, farmers could increasingly rely on illegal groundwater extractions. Increasing water charges has also the advantages of providing incentives to farmers for a more efficient use of water and reducing government support, which could then be used to achieve other policy objectives.

Turning to the negative aspects of cost recovery, higher water charges may impact significantly on farmer's income (Giannocaro *et al.*, 2010; Gallego-Ayala *et al.*, 2011). In this sense, our study has identified the margin for increasing water tariffs within the limits of farmers' WTP and the potential for increasing such WTP by acting on some of the factors that have been identified as related with WTP. Increasing water tariffs for collective irrigation supply services could also put additional pressures on groundwater sources (Dono *et al.*, 2010), and some of the farmer's answers suggest it. However, it could also be argued that if tariffs were not increased and the surface water supply services deteriorate, farmers would also rely more on groundwater. In the end, the problem is the lack of effective public control of illegal groundwater pumping. Water pricing alone is not enough to increase efficiency without additional policy measures that improve water governance in the area. Our results suggest that there is a need for reforms in the Algerian irrigated sector if the Government wants to ensure its financial viability on the long run. Some of them are related with water governance, *e.g.* the installation of individual metering devices and the control of illegal water abstractions, while others require interventions on the fields of agricultural policy and land reform.

Last, another relevant issue is the modernization of irrigation districts. Although farmers are in general satisfied with the irrigation water supply service, there is a need to improve the infrastructures of the West Mitidja irrigated area in order to reduce water distribution losses, improve the timeliness of water delivery and increase the level of supply reliability. An analysis of farmers' WTP for such modernization plan would be necessary to analyse the cost and benefits of its implementation.

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