Estimating household water demand and willingness-to-pay to maintain future access: evidence from Central Tunisia

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Abstract

Knowledge of the determinants influencing domestic water demand and information on the value households place in the water services constitute essential ingredients in the design of water policy in a context of increasing water scarcity due to climate and anthropic higher pressures. In this challenging environment, Tunisia, as numerous developing countries, is facing a high level of poverty and a current dual water supply, with households safely connected to water supply network and other poorly or not connected at all. Since the revolution of 2011, water access has become the core of the demand for an overall improvement in rural living conditions. Water demand has changed there, calling into question the current national balance in terms of resource and sector financing which will impact all the country. An improvement of water demand determinants in rural areas may be useful for general water sector planning and strategy design, as it documents the opportunity and the consequences of adding new connections in rural areas while helping to estimate future water consumption and wastewater production. Another specific objective is to estimate price elasticity in various contexts, which also may help anticipate responses to other demand instruments in order to encourage water conservation in a global context of water scarcity. Then, the paper informs on a really nuanced degree of acceptance between localities of financial participation for water connection through willingness-to-pay analyses.

This study analyses water demand using an original panel data at an individual level based on a survey conducted in 2014-2015 in the Governorate of Kairouan. The price elasticity is estimated at -0.1 for rural community-piped households. In non-piped rural areas, water demand seems to be essentially driven by variables characterizing the physical accessibility to water source. Households expressed a large willingness-to-pay to get an individual connection revealing the high value households place on the water services.

Key words: demand estimation, contingent valuation, household survey, household water demand, price elasticity, willingness-to-pay, Tunisia

JEL: C21, C23, D12, Q21, Q25

1. Introduction

Knowledge of the determinants influencing domestic water demand and of willingness-to-pay to maintain water access constitute an essential ingredient in the design of water utilities' policy in a context of increasing water scarcity due to climate change and anthropic higher pressures. When water demand is increasing and availability of water resources is not guaranteed or become too expensive due to technology required, water policy should encourage water demand management measures to prevent imbalance.

An important number of studies on domestic water demand have already been conducted in industrialized countries and some studies focus on the case of developing countries. As for now, empirical evidence from southern Mediterranean countries is still very scarce, especially from studies focusing on both urban and rural areas in a specific region.

The present paper presents a case study focusing on central Tunisia comprising urban and rural areas, in the Governorate of Kairouan. Since the revolution of 2011, water access (for domestic and also agricultural needs) has become the core of the demand for an overall improvement in rural living conditions (Gana 2012). In particular, water demand in rural areas has changed, calling into question the current national balance in terms of ressource and sector financing in Tunisia which will impact all the country, because of current unbalanced water budget and the need to participate national effort to allow access to all.

The paper adds to the recent literature dealing with the issue of water demand in southern Mediterranean countries in the particular context of water scarcity. In the present paper, we propose to focus on rural non-SONEDE households only. The first objective is to improve the knowledge of water demand determinants in rural areas, by conducting an in-depth analysis at household level, contrary to previous works undertaken in Tunisia which focused on the regional district level solely in the urban sector (Ben Zaied 2013; Ayadi et al. 2002; Binet & Ben Zaïd 2011; Sebri 2013). This improvement may be useful for general water sector planning and strategy design, as it documents the opportunity and the consequences of adding new connections in rural areas while helping to estimate future water consumption and wastewater production, as ground water preservation is also becoming an issue. Another specific objective is to estimate price elasticity in various contexts, which also may help anticipate responses to other demand instruments in order to encourage water conservation in a global context of water scarcity. Then, the paper informs on degree of acceptance of financial participation for water connection through willingness-to-pay analyses.

This paper is organized as follows: after a presentation of the background, the methodology for data collection is explained. Then, the paper addresses the water demand function estimate and analyses willingness-to-pay, before concluding.

2. Background

Water resource

In Tunisia, total renewable water resources per capita were estimated at 415 m^3/inhabitant for 2014 and they could fall to 345 m^3 in 2025 (Hamdane, 2007 quoted by Sebri 2013). The external dependence is low at national level as only 9.1% of national resources came from abroad in 2014 (FAO Aquastat database), which has favored the development of coastal (touristic) towns. But these territorial choices for the economic development of the country did not take into account the geographical imbalance of water resources (Touzi et al, 2010), leading to major transfer investments being made: coastal zones (Cap-Bon, Sahel, Sfax) has to derive 55% of their supply from the regions of the north and north-west which transfer 74% of their production (SONEDE, 2008 quoted by Touzi et al, 2010). In particular, the Kairouan area is supplied from an aquifer renowned for its quality and which supplies other regions in Tunisia via large-scale transfer infrastructures.

Water access

In Tunisia, the national public operator SONEDE serves 100% of urban households and 50% rural households nationwide. Almost all its customers are served by individual connections (IC).

In unserved rural areas, water service is the responsibility of the Ministry of Agriculture, who funds initial infrastructure investment and entrusts systems' exploitation to water users' associations (GDA[1]). Initially, systems managed by the GDAs were designed as simple systems supplying water for irrigation, husbandry and domestic supply through collective water kiosks. Rural communities were supposed to build the capacity to manage them through the GDAs.

In the 2000s, this model was weakened by several governance, technical and financial problems which led to a degradation of water service: increasing complexity of systems, loss of confidence in GDAs managers from members suspecting them of fraud, insufficient revenue to cover operating and maintenance costs, lack of technical skills (interviews with civil servants of the ministry and GDAs, 2014; Ministère de l'Agriculture BPEH et DGGREE et al. 2013).

Following the 2011 revolution, the aspirations of rural population to benefit from the same service as their urban counterparts (continuous service, at home, affordable) increased. In the short term, in a significant number of GDA, these claims justified the proliferation of illicit ICs, water theft, diversion of fresh water to irrigate and/or refusal to pay water bills, and this behavior led to the interruption or significant deterioration of the service.

[1] GDA for Groupements de Développement Agricole

With the systems extended beyond their capacities due to the rise in water theft and illicit connections, energy consumption and thus electricity bills have increased considerably. And this increase, combined with the fall in revenue, has exacerbated the GDA deficits which are now structural in nature. The GDAs quickly found themselves unable to pay their electricity bills to the STEG, the national operator, which regularly cuts the electricity supply to the systems, thereby interrupting the water supply, until the bills are paid (interviews with the GR-CRDA in 2014 and observations on site). At the time of writing, discussions were ongoing between the CRDA, the STEG and the municipalities in an attempt to find a solution to the GDAs' debt problems, with the sums involved quite considerable. Households who are served neither by SONEDE nor by a GDA rely on their own well (with motor pump or not), other water kiosks, springs, rainwater harvesting in cisterns on rooftops (Zekri & Dinar 2003), or neighbors' individual connection.

This papers concerns a specific zone located in central Tunisia: the Governorate of Kairouan where 100% of urban households and 39% of rural households are supplied by SONEDE (through ICs), 50% of rural households are supplied by GDAs (16% by individual connections and 34% by kiosks) and 10% are not supplied (SONEDE estimate in 2014). After the revolution, this governorate was particularly affected by illegal connections, boreholes and water theft in rural areas.

At the institutional level, the current issue is that of the future management of rural areas in light of the current difficulties of a lot of GDAs. The debate at present is between those who call for the improvement and maintenance of the GDA model and those in favor of the extending the scope of SONEDE to rural areas. Needless to say the rural populations, who are keen to enjoy the same coverage as the urban populations, are in favor of "the arrival of SONEDE" in order to benefit from a non-stop service at home which is less expensive than that provided by the GDA. However, the level and current tariff structure of SONEDE, the current costs of which are not actually covered, would not enable it to incorporate less dense networks without a significant increase in prices and/or large-scale subsidies. In 2013, a Ministry of Agriculture note specified that the aim of 12th five-year development plan was, among other things, "to improve the coverage rate in rural areas to 97% […] to generalize individual connections for new projects or to rehabilitate the systems" (Ministère de l'Agriculture BPEH et DGGREE et al. 2013). The authorities therefore seem to have agreed the generalization of individual connections in rural areas, although it may be implemented in the medium-to-long term depending the localities, due to high hydraulic constraints.

Water tariffs

In rural zones supplied by GDAs, the price of water is not homogenous. The GDAs therefore bill customers supplied by kiosks, and thus less conveniently, an average of TND[2] 0.2 to TND 1.2 per cubic meter of water (personal communication, M. Mnajja Ministry of Agriculture, 2014 and observations in the field).

When public access was privatized by illicit connections (**Table 1**), pricing per cubic meter was adopted, with a price ranging from TND 0.4 to TND 0.75.

Water access	Price	Locality
Individual connection (piped households)	0.400 TND/m^3 0.500 TND/m^3 0.750 TND/m^3	Rmadhnyia Nahala, Ruissat, Zbara Mtayria
Water kiosk	0.020-0.025 TND per 20 litres + transport charges (up to 20 TND)	Cheri-Chira, Ganzhour, Nahala, Rmadhniya, Ruissat
Tanker delivery	20 TND (3 m^3) 30 TND (5 m^3)	Nahala (suffering from long-run shortage)
Water container (20 or 40 litres)	1 TND	Ruissat

Table 1: Type of access, price of water and place of access

The price of water paid by non-piped users is even more variable, depending on the water access modes (**Table 1**): for a 20-litre container filled directly from a kiosk, the price is TND 0.020 while the same container delivered to the home is billed at TND 1. Tanker deliveries are also possible, leading to a price of about TND 6 per cubic meter.

These price lead often to bills higher than those paid by SONEDE customers. SONEDE's water tariff currently applied is uniform throughout the country. It is topped with a sewage collection and treatment charge, this service being operated by another national public operator, ONAS.

Water bills in urban areas and rural areas served by SONEDE include then one or two parts depending on the presence or not of sewerage. Water bills vary highly and by steps (**Figure 1**) both services having adopted binomial tariffs with increasing blocks. Concerning the water part, SONEDE applies a fixed part depending on the diameter of the water meter. The variable part is priced following an increasing banded pricing structure beyond 40 m^3, the water tariff grows fast with water consumption, because all consumption is charged at the rate of the last band; this strongly incites consumers to save water.

[2] The exchange rate is EUR1=2.24 TDN as of 10/03/2016, it was EUR1=2.25 TDN at the time of the research (01/01/2015).

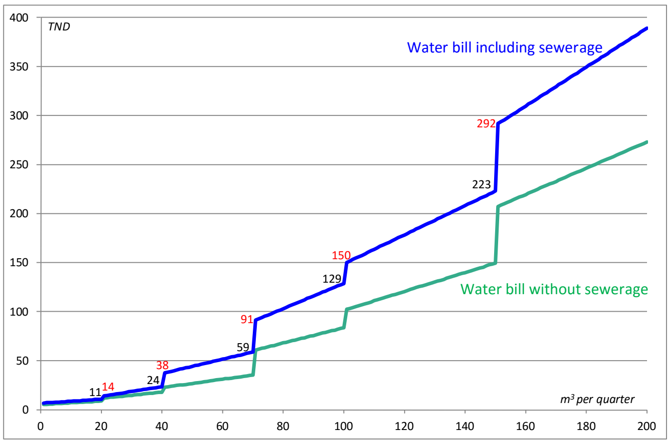

Figure 1: Water bills (incl. VAT) paid quarterly by Tunisian households connected to SONEDE (TND), in 2014, up to 200m³ quarterly consumption

3. Data

The data set used is original as it comes from a household survey we carried out in 2014-2015 in 16 localities in the north-west of the Governorate of Kairouan.

Methodology

Before starting the survey, targeted interviews conducted with institutional actors at national level (Ministry of Agriculture, SONEDE) and regional level (CRDA[3], DR SONEDE) served to characterize the general water access situation at local level, to identify the different water access modes and supply situations and to choose the locations (or sectors) to be surveyed.

At the same time, a draft questionnaire was tested with twenty urban and rural households. On the basis of the results of the first questionnaires and different discussions with the households and institutional actors, the questionnaire was adjusted and translated into Arabic.

Five students (two women and three men) from the region with at least two years' higher education and bilingual in French and Arabic were recruited and trained. They were chosen on the basis of their comprehension of the questionnaire, the objectives, the method and their ease in the field.

The survey work at each site was carried out in two stages. Initially, we visited each location after being announced by the SONEDE Regional Director or being accompanied by a CRDA's civil servant in order to meet the local authorities and, where applicable, the local manager of SONEDE, to visit the sites, to see the supply systems and to locate the different accommodation districts. Subsequently, the entire team including the interviewers travelled to the locations to conduct the interviews. Each interview, lasting on average 20 to 40 minutes, was conducted one-to-one with an

[3] The CRDA is a regional administration under the authority of Agriculture Ministry and who is in charge of bringing technical support to GDAs.

adult member of the household either at home or at the water supply site. To ensure statistical representation of the observations while taking account of material constraints inherent to research (in particular logistical and budgetary, but also the workability of the sample to control the quality of the information collected), the decision was made to collect at least 30 questionnaires for each location (or per district in urban areas).

It was no possible to draw households at random using a table of numbers in each location for budget reasons, time reasons, logistical reasons (the dwellings are widely spread in rural areas) and the availability of the survey base. However, the adopted method to choose households tried to be close to the random sampling procedures: the interviewers were assigned to each district with the aim of conducting a minimum number of surveys per investigator, determined according to the estimated population of each site, and were instructed to cover the geography of the site and not interview neighboring households. Three survey sessions were conducted in the locations between autumn 2014 and spring 2015.

Final sample

The 16 localities surveyed were selected according to the physical (drinking water distribution or irrigation network, no one, self-alimentation), institutional (SONEDE, GDA, un-served), and economic criteria of water access.

- 8 locations supplied by SONEDE, 3 in urban areas, 1 in a periurban area and 4 in rural areas supplied for different durations (4 months, 2 years, 15 years, 25 years);
- 7 rural locations supplied by GDAs with contrasting situations in terms of water resource (autonomous water source, SONEDE pipe, purchase form another GDA), mode of water access (legal/illegal individual connection of the household or a neighbor, kiosk, water vendors, well), continuity of service (continuous supply, frequent interruptions, interruptions lasting several months or years);
- 1 rural location unserved.

The sample size reached 655 households with 73% of the people interviewed were heads of household, 20% their spouse and 7% another adult within the household. Among the 655 households, 60% are located in urban or periurban areas and 40% in rural areas. In the SONEDE areas, 95% of households had an individual connection. In the other locations, 54% of households have an individual connection to a GDA network (function or non-functional at the time of the survey, either illicit or licit) and 46% have no IC. In four locations managed by GDA, the individual connections installed are considered as illicit while in one location they were installed under the control of the CRDA. Two locations benefit from a service which is occasionally intermittent but without long interruptions, one location suffers from an intermittent service which does not cover

all the housing areas and two locations had had no water at the individual connection for several months when the survey was conducted.
The present study focuses on the 266 non-SONEDE households solely.

Questionnaire and additional data collection

The survey instrument (200 questions) consisted of several parts. The first section aimed at drawing a socio-economic profile of the households and described their living conditions. A second section identified the modes of water access, and evaluated the current level of consumption and associated costs. The third section determined the coping behaviors and strategies in the event of a service interruption or a change in the water access modes.
The main originality of the questionnaire lies in fact that we have endeavored obtain a robust estimation of water consumption and its variability (between summer and winter, according to the water access mode for a single household, for example during an interruption), when this is conducted without an individual meter, the main difficulty encountered in these contexts (Nauges & Whittington (2009). Only the SONEDE-piped households have meters which are read on a quarterly basis. For the latter, it was possible to obtain the information directly from SONEDE as the households communicated their customer number.
For GDA-piped households, no meter could be read (meter absent, hidden, illegible, removed). Consumption was estimated by comparing the following information collected from the households: i) an equivalent in litres per day they believe they consume, ii) the volume consumed in the event of a shortage and the difference (as a number of containers) between usual consumption via the individual connection and the same consumption in the event of a shortage, iii) the volume consumed before getting the individual connection and the number of additional containers they believe they now consume with the individual connection. It would appear that these questions worked well (high response rate) and provide similar values.
Finally, with regard to non-piped households who are supplied via a source outside the house, the means of water supply was recorded per period and per type of access, and in particular the number of containers and the frequency with which they are filled were indicated by the households. The volumes declared can be considered as reliable for three reasons: i) access is often relatively far from the dwellings and the households procure water a limited but regular number of times per period, ii) the households have a limited number of empty containers and the containers are expensive, iii) the number of containers and their capacity were summarized at least twice by the investigator through different questions posed during the interview.

The survey data were supplemented with daily meteorological data from the Weather Information Service provided by OGIMET using specific data come from the NOAA system[4] which relays the records of a station based in Kairouan.

4. Water demand estimate

Brief literature review

The literature on water demand modelling function is relatively extensive and has already given rise to several recent summaries including 3 meta-analyses (see Espey et al. 1997; Dalhuisen et al. 2003; Sebri 2014) and 6 literature reviews (Arbués et al. 2003; Baumann et al. 1998; Worthington & Hoffman 2008; Nauges & Whittington 2009; House-Peters & Chang 2011).

In industrialized countries, where drinking water supply through individual connections is relatively generalized, the aim of determining factors explaining household water consumption is to help forecast future water consumption (planning) and to anticipate the reactions of the consumers when implementing demand management policies, in particular pricing reforms. The data used are the most frequently derived from aggregate customer consumption data (for example for an entire municipality) provided by the water suppliers. At this level, however, as underlined by Nauges & Whittington (2009), certain socio-economic information only available at the individual household level is not, by definition, incorporated. We are therefore dealing with systems which we assume provide a homogenous service in terms of price, water quality and service continuity and in which any variability in access to the water service is erased or at least averaged out.

In functional terms, the models usually take the form of the following classic single equation:

$$q = f(p,x)$$

where q represents water consumption, p the price of water and x a vector of the household and accommodation characteristics.

The meta-analyses identify two common types of functional form adopted by studies: i) linear functions which do not provide a constant elasticity value at all points on the demand function and ii) log-linear functions with the advantage of providing a constant elasticity value for all points on the demand curve.

Espey et al. (1997) and Dalhuisen et al. (2003) find no significant difference between linear and log-linear forms while Sebri (2014) concludes that there is a significant difference, albeit small, between log-linear forms. Several regression forms are tested in the literature, but the three meta-

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[4] National Oceanic and Atmospheric and Administration published by United States Department of Commerce.

analyses cited above highlight the absence of any significant difference between OLS estimators and other estimators (instrumental variables, fixed effects, random effects).

The factors most often identified as being significant are the price of water, household income, climatic variables, household size and composition, the presence of non-tariff demand management instruments (Worthington & Hoffman 2008), the presence of household appliances (Nauges & Whittington 2009), accommodation characteristics and the different interior and exterior uses made of water (Arbués et al. 2003).

Particular attention is generally paid to the results of the price and income elasticities, although the values are low – often below 1 – due to the fact that water is a non-substitutable good and that users have only a limited price perception when the bill represents a small share of income (Arbués et al. 2003). According to Espey et al. (1997), the average elasticity observed in 24 dedicated studies in the United States is -0.51 (90% between 0 and -0.75), while Arbués et al. (2003) note an income elasticity of between +0.1 and +0.4 in the studies they have reviewed.

In developing countries, there are fewer studies available on water demand. To the best of our knowledge, the state of the art proposed by Nauges & Whittington (2009) is the only recent analysis dedicated exclusively to studies conducted in developing countries. According to the authors, the use of (or the access to) numerous water sources by households is one of the characteristics of water provision in these countries. The difficulty in obtaining reliable and complete information for all the water systems available to the households would explain the smaller number of studies conducted in this context. The socio-economic household survey appears then as one of the strategies to collect such data.

In the context of developing countries where access modes are not homogenous and several types of supply may be available on a same location, it is important to control that certain household characteristics (observed or otherwise) are not correlated with the type of source and with the level of consumption - since water consumption level will then depend on the water access mode. Then a “source choice model” may be implemented to avoid a possible risk of sample selection bias in such a situation. Correlation between household characteristics and type of source may occur when the households have access to several sources and choose one specific sources as their main source or because by choosing their place of residence, it is deemed that households have chosen their means of water supply (Larson et al, 2007) or even that the municipalities take the decision to supply a population with one or other system (public water kiosks, tanker truck for example) according to the household characteristics (as they can determine their capacity and willingness to pay, for example) (Nauges & Strand 2007).

Once the source choice issue has been solved, the water demand function can be estimated. For households collecting water exclusively or primarily from one single source, studies usually estimate a water demand function per type of source or one equation per sub-group of households differentiated by their water access mode (Nauges & Whittington 2009). In the case were multiple sources are simultaneously used by households, several demand functions may be combined to measure substitutability and complementarity relations between the sources (see for instance Nauges & Strand 2007; Nauges & van den Berg 2009).

With regard to the water demand function, the same estimators are used as for industrialized countries (OLS, instrumental variables, fixed effects, random effects). The dependent variable is consumption per household or per inhabitant while the explanatory variables are water price, household characteristics (income, size, composition, family head profile), accommodation characteristics (size, type, garden, equipment, sanitary facilities), season, climate (rainfall, temperature) and water access (organization of fetching water, service continuity, water quality) Nauges & Whittington (2009).

Model specification

We consider that a source choice is not relevant applicable as the households are under too many constraints. First, households generally have access to a single source for their domestic consumption in the examined region (of course considering the main supply and not the periods of interruption when households are looking for alternative sources). The choice of which authorities should set up the infrastructures is then based on exclusively physical (availability of the resource), geographical (differences in altitude, distances) and land occupation (housing density) criteria.

In light of the strong variations in consumption recorded between the two seasons (summer and winter), we choose to handle data as a panel in order to retain this seasonal dimension which can be useful both from an economic standpoint if we wish to introduce regulatory tools for demand (for example seasonal pricing) and from a technical standpoint to measure water needs.

For each household, we considered the reference season “summer” or “winter” to be the most recent season past. The panel data was created by pooling the observed responses for each household and the meteorological data from OGIMET. With each of the two reference seasons “winter” and “summer” for each household, we matched the corresponding climatic variables and, only for households for which the bills were available, the volumes invoiced for these two reference seasons. In light of the fact that not all households were interviewed during the same month (3 sessions spread over 1 year), not all households have the same two reference seasons. In the panel, certain variables vary with the individuals and time (consumption, price, climate), while others are invariable over time (socio-economic characteristics of the households and housing, water access mode). Due to the missing data, the panel is unbalanced.

Household water demand was then estimated using random effects generalized least squares, for three reasons. First, the random effects model distinguishes itself from the fixed effects model by the fact that it considers that the individual specific effects are not deterministic but random. In our case, we work on survey data, a non-exhaustive sample drawn at random from a population, and it is preferable to consider that the individual effect is random and non-deterministic (Baltagi 2008). Then, our model combines an inter-variability (between) and an intra-variability (within) and thus satisfies the requirements of a random effects model which can be interpreted as a weighted average of the OLS model and the fixed effects model. In our case, the unobserved heterogeneities can be of different dimensions: invariable over time and specific to each individual (cultural and religious practices, physical characteristics, etc.) which are sensitive variables to be included in surveys and difficult to estimate; variable over time but in a manner specific to each individual (exceptional use of other sources, creation of new temporary uses, temporary increase in the number of supplied people, etc.). Finally, in more practical terms, this approach allows time-invariant household specific explanatory variables (such as income, household size) to be included in the demand equation since in the fixed effects model, these variables would have been absorbed by the intercept. The basic form of the equation for the water demand function is as follows:

$$Q_{is} = \alpha + \beta X_{is} + \gamma Z_i + \mu_{is}$$

As a log-linear specification was retained, the equation takes the following form:

$$\text{Ln } Q_{is} = \alpha + \beta \ln X_{is} + \gamma \ln Z_i + \mu_{is}$$

With Q_{is} the log of the consumption of individual i in season s; α the intercept, $\ln X_{is}$ the log of the explanatory variables which vary in the two individual and seasonal dimensions, $\ln Z_i$ the log of the explanatory variables which do not vary in the single individual dimension; β and γ the vectors of the parameters we want to estimate and the error term μ covering two dimensions, individual and temporal (between-entity error and a within-entity error).

<u>Description of variables and selected summary statistics</u>

After data-cleaning, the usable sample size consists of 115 GDA-piped households and 100 non-piped households. Some households were excluded from the analysis of water demand that we will examine below. These are GDA-piped households and households living in the unserved locality where consumption measurements are not deemed sufficiently reliable.

It is important to specify that all the following analyses deal with the households' main means of supply and not the alternatives used by households when subject to long periods of interruption to the supply alimentation.

As for GDA-piped households, the vector of explanatory variables includes the average price (as a log, varying per individual and per season), the quarterly household income (as a log, varying per individual), the number of people per connection or per household (as a log, varying per individual), the existence of a dedicated, separate bathroom (0/1, varying per individual), the existence of a vegetable garden on the land (0/1, varying per individual), household ownership of a well (0/1, varying per individual), the aggregate number of hours of water supply interruption (as a log, varying per individual and per season), and the maximum average temperature (as a log, varying per individual and per season as the individuals do not all have the same reference season).

For non-piped households, other specific variables are included: the person responsible for fetching the water (1 it is a woman, varying per individual), the means of transporting the water (1 if on foot, varying per individual), the distance to the source (as a log, varying per individual), the frequency of water collection (log, varying per individual).

These variables are described in the **Table 2** along with a brief discussion of variables. The seasons "summer" and "winter" indicate the reference seasons for each household (the last season past) and correspond to 3 months (June-August for the summer and December-February for the winter).

			GDA-piped households		**Non-piped households**	
Variable		Unit	Mean	Std dev	Mean	Std dev
conso	3-month water consumption in winter	m^3 per household	12.8	10.9	11.8	10.1
	3-month water consumption in summer		14.5	11.0	13.7	12.1
conso.i	3-month water consumption in winter	m^3 per capita	3.0	3.1	3.2	3.2
	3-month water consumption in summer		3.4	3.2	3.7	3.2
price	Average price winter	TND per m^3	2.8	2.1	1.4	3.8
	Average price summer	TND per m^3	3.0	2.1	1.4	3.8
income	Household income	TND per quarter	1597	823	1563	729
hh.size	Household size (or people per connection)	Number of inhab.	5.3	2.4	4.4	2.0
bathroom	Bathroom (separate room)	Yes = 1	34%		6%	
shortage	Cumulative hours of shortage in winter	Hours	120	264	51	231
	Cumulative hours of shortage in summer	Hours	277	384	95	309
garden	Vegetable garden	Yes = 1	7%		0%	
well	Own a private well	Yes = 1	12%		0%	
frequency	Water collection frequency in winter	nb of times per day			1.50	0.87
	Water collection frequency in summer	nb of times per day			1.80	1.42
woman	The woman is in charge of collecting water	Yes=1			79%	
walking	Walk to go to fetch water	Yes=1			43%	
distance	Distance to the water source	meters			607	1449
temp.max	Average maximum daily temperature	°C	19.0	0.3	19.0	0.3
temp.max	Average maximum daily temperature	°C	36.7	0.1	36.7	0.0

Table 2 Descriptive statistics (unweighted data)

Consumption and price

Quarterly consumption of GDA-piped households is estimated at between 13 m^3 (winter) and 14 m^3 (summer) per quarter, it represents respectively 33 and 37 liters per capita per day. With regard to non-piped households, average consumption is between 3 (in winter) and 4m^3 (in summer) per quarter per habitant (35 liters per capita per person). It seems to correspond to a minimum of consumption as it seems that the variation between summer and winter season is very low, on average.

As for GDA-piped households, as explained previously, we only consider here the principal water access mode and not the alternative one in case of a long period of shortage. Following our methodology GDA-piped households were asked different questions with a view to using different ways to estimate the volumes consumed, but not measured by a meter. An average of the obtained values was calculated for each respondent household in liters per day before being calculated for the quarter taking in account a coefficient of discontinuity of the service. It should be noted that the households are affected differently by these interruptions as tap pressure depends on the position of the dwelling within the network. The results would appear to be relatively reliable if we work with the average across the 5 locations: the quarterly volume consumed per inhabitant would be about 15 m^3 according to our calculations based on the volumes produced (communicated by CRDA) and if we assume a rough distribution output ratio of 70%, while our sample indicates a consumption of 14 m^3.

Price

For GDA-piped households, the average price indicated corresponds to the ratio between the billed amount (that the household claims to pay over a period) and the estimated volumes they have consumed over the same period. This price is higher than the official prices practiced. This is not surprising in that the households claimed to pay flat-rate bills according to fixed schedules (every two or three months) while the service is not continuous.

Income

Another key independent variable in the model of the demand function is that of income. To limit the bias inherent to household surveys with regard to income (Basani et al. 2008), we interviewed households both with regard to their spending and their income while not omitting to ask them to specify their reciprocal periodicity. We then developed a budget indicator corresponding to an average between the maximum income level and the minimum spending level. This indicator enables us to ensure the reliability of the income variable. The incomes considered include work income and any rent, social aid or other money transfers (net) received.

Other variables

On average, the households in our sample have 5.38 members for GDA-piped households and 4.4 for non-piped households (4.4 on average for the entire governorate, RGPH 2014).

A variable which serves as a proxy of service continuity was calculated here: the aggregate number of hours of interruption recorded over a season.

The variable *bathroom* indicates indoor use of water, showing whether the household has a dedicated washroom in the dwelling (34% for GDA-piped households and only 6% for non-piped households). It should be noted that the other sanitary equipment variables such as flush toilets, washing machines and dishwashers were not incorporated into the analyses due to multi co-linearity with the variable *income*. Similarly, the variable *dwelling area*, which could indicate the number of water outlets, was not incorporated as it proved to be co-linear with the variable *income*.

The variable *garden* indicates the possible outdoor uses of water and the variable *private well* water from which can be used for outdoor purposes.

Other water access variables are included for non-piped households including distance to the supply source (on average 607m), supply frequency (on average between 1.5 and 1.8 times a day), people responsible for fetching the water (women in 79% of cases) and transport (on foot in 43% of cases).

Finally, two climatic variables were initially selected: aggregate precipitation and maximum seasonal average daily temperatures recorded.

We expect the variables *income*, *household size*, *garden*, *temperature* and *bathroom* will positively influence the consumption, while the variables *price*, *rainfall*, *shortage* and *private well* will influence it negatively. For non-piped households, we assume that access variables would impact water consumption, positively for the variable *frequency* which grow when it is more easy to go to the access point, and negatively for the variables *distance*, *walking* and *woman*.

Econometrics results and discussion

The absence of co-linearity between the explanatory variables was tested previously with the Variance Inflation Factor (values ≤ 2). The precipitation variable was not retained due to its co-linearity with the temperature variable. We preferred keeping the temperature variable since very few outdoors uses were recorded.

It was feared that the frequency variable, which can be interpreted as a variable of accessibility to the source (the more the source is accessible, the more often the individuals can collect water), was linked to the variables of distance and means of transport, but a VIF test validated the absence of co-linearity between them.

Table 3 describes the results of water demand function regressions.

Dependant variable: consumption, m³ per capita per quarter (log)	GDA-piped households n= 115			Non-piped households n=100		
	Coef.	Std errors	P>z [1]	Coef.	Std errors	P>z [1]
Price (log)	**-0.123**	**0.062**	**0.000*****	0.015	0.012	0.226
Income (log)	**0.383**	**0.101**	**0.000 ******	0.061	0.113	0.591
Hh.size (log)	**-0.888**	**0.115**	**0.000*****	**-0.646**	**0.122**	**0.000*****
Bathroom (dummy)	**-0.180**	**0.108**	**0.095***			
Well (dummy)	-0.108	0.202	0.597			
Garden (dummy)	-0.051	0.286	0.859			
Shortage (log)	**-0.000**	**0.000**	**0.000*****			
Distance (log)				**-0.096**	**0.028**	**0.000*****
Woman (dummy)				**-0.655**	**0.131**	**0.000*****
Frequency (log)				**0.470**	**0.068**	**0.000*****
Walking (dummy)				**-0.573**	**0.138**	**0.000*****
Temperature max (log)	**0.366**	**0.049**	**0.000*****	**0.215**	**0.042**	**0.000*****
Constant	**-1.561**	**0.787**	**0.048***	1.791	0.938	0.058 .
Fisher test: H0: x=0 **P> F-statistic**	19.743 on 8 and 217 DF 0.000***			34.5458 on 8 and 191 DF 0.000***		
Adj. R-Squared:	0.404			0.521		
Number of observations	226			200		
Number of groups	115			110		
Breush and Pagan Lagrangian multiplier test for random effects: H0: Var(u)=0 **Chi2(1)** **P > chi2**	100.53 0.000***			76.02 0.000***		

[1] Here ***, **, *, and . denote statistical significance at 0.01%, 1%, 5% and 10%, respectively

Table 3 Random Effects water demand estimates

Both of the demand functions are significant at the 0.1% threshold, the coefficients of the variables retained are generally significant and all have the expected sign with regard to economic intuitions and the results of the literature relating to water demand. The null hypothesis in the Lagrange Multiplier Test - two-way effects (Breusch-Pagan) that varies across individuals is zero were rejected. Significant differences across individuals confirm that there is a panel effect and that a component errors model is more appropriate than a simple OLS regression. Coefficients have been corrected from heteroscedasticity.

The simple significance tests demonstrate that the GDA-piped households are significantly sensitive to prices, but only in a very weakly negative manner (-0.1 significant at the 1% threshold). Sensitivity to income is significantly positive (+0.3 significant at the 0.01% threshold). The shortage variable is significantly null, which is logical if we are aware of the practices of GDA-piped

households: the taps are more often than not located at the edge of the plots and the households call on intermediate stocks when using the water (filling containers). During interruptions, the household consumes the intermediate stocks and the reserves from this source. The three last variables “bathroom”, “well” and “garden” are not significant.
With regard to non-piped households, price elasticity and income elasticities are not significant at the 5% threshold. It would seem that the pertinent variables are not price and income but variables relating to physical access to the resource. The accessibility of the source, using the proxy of frequency, is significant, as well as the variable indicating that a woman is responsible for collecting the water and the fact that water is transported on foot: the higher the frequency of water collection, i.e. the more it is accessible (to the person responsible for collection), the more consumption increases; when the woman is responsible for collecting the water, consumption falls and when animal-drawn or motorized transport solutions are not available, consumption decreases as well.

As for GDA-piped households, the value of price elasticity can be compared to other ones found by studies conducted in developing countries, which usually range from -0.3 to -0.6 for individual connections (Nauges & Whittington 2009). When we look more specifically at those conducted in the southern Mediterranean sub-region providing data from 1980 to 2008, we observe higher price elasticity values ranging from -0.2 to -0.8, with a number of outliers (Ben Zaied 2013, Sebri 2013, Binet & Ben Zaïd 2011, Ayadi et al. 2002, Zekri & Ariel Dinar 2003, Lahlou & Colyer 2000, Kertous 2012, GTZ customer survey, Makary Consulting, 2009, cited by USAID Egypt - Water Policy and Regulatory Reform 2012, Al–Najjar et al. 2011, Al-Karablieh et al. 2012, Salman et al. 2008).
Among those studies, only Zekri & Dinar (2003) investigated small systems, the authors present two extreme values calculated by a model based on aggregated data from 1983 to 1992 for rural Tunisia: -1.3 for households served by GDA (at this time access was only collective through water kiosks) against -0.2 for rural SONEDE-piped households. The authors explain this marked difference by the fact that GDA-households might be poorer than the others, a position confirmed by their respective water consumption level (63 m^3 per year per household for GDA households and 137 m^3 per year per household in SONEDE villages). In contrast, the four recent studies conducted at an aggregate level (the district level) in Tunisia exclusively in the SONEDE perimeter (Ben Zaied 2013; Sebri 2013; Binet & Ben Zaïd 2011; Ayadi et al. 2002) converge to show that small consumers are still less sensitive than larger ones and that it could be explained because they are mostly low-income households whose consumption is the minimum level necessary to meet basic needs.

Even if our study is conducted at an individual level (and not like the previous one at the district level in the SONEDE perimeter) and focus on another distribution system, we can apply the same reasoning to results obtained from our two sub-samples: the very low price sensitivity for GDA-piped households, and even null sensitivity for non-piped, can be explained by the very low consumption level which tend to incompressible water needs.

5. Willingness-to-pay to improve future access

Research design

In Tunisia, and in particular in the Governorate of Kairouan, the duality between the two systems of drinking water access is becoming increasingly unacceptable to rural households in villages not served by SONEDE. While certain villages enjoy a high-quality service, albeit with collective but also local and uninterrupted provision offering good pressure at a reasonable price, the situation in other villages is serious. Due to a variety of complex problems which are technical, institutional and financial in nature (see earlier), the conditions of access to water have become very difficult in certain cases. Some villages are subject to persistent pressure problems and an intermittent service with longer and shorter interruptions (ranging from a few hours per day to several months per year), forcing inhabitants to turn to alternative sources which are either relatively inaccessible (several kilometers away) or very costly (for example deliveries to the home by water sellers at a very high price). For households in this situation, the very strong desire for an improved service such as that provided by SONEDE is all the greater as numerous rural villages have already been incorporated into the SONEDE perimeter. In a single administrative sector, therefore, some more densely populated villages which are located near the secondary SONEDE network can be supplied by SONEDE while others still have no safe access to water.

In the governorate of Kairouan, civil servants report that since the revolution of 2010, the local populations have constantly requested an improvement in the conditions of access with a generalization of individual connections. Nevertheless, it is important to note that the households have a false image of the price of water home service. The SONEDE tariff has become the reference point whereas it is now insufficient to cover the current and future costs of the service. The current national tariff does not cover the current costs of water supply. Moreover, SONEDE will face increasing demand due to population growth within the current perimeter and, potentially, the needs of newly-supplied rural localities to enter SONEDE's perimeter. To satisfy this increasing water demand, expensive technologies will be required: new water transfer structures are currently being studied and seawater desalination units are already being planned and/or under construction. In the very short term, a price increase is thus inevitable (it is being studied even as we speak) to enable SONEDE to fulfil its missions while, in the longer term, prices may even have to rise further.

In this context, those households not connected to the SONEDE network were questioned with regard to their willingness to pay for an individual connection to a "SONEDE-type" network with a view to improving their access with an individual connection on their plot, continuous service and satisfactory pressure.

In particular, households connected to the GDA were asked about their willingness to make a financial contribution to renovating the system in order to improve and ensure the sustainability of their existing individual connection. The households not connected were asked if they would be willing to pay to obtain an individual connection. The households were then asked if they would accept to pay a regular bill once connected. This second question is pivotal in light of the current context in certain GDAs where connected households refuse to pay bills to the GDA, despite the fact that few of them mentioned this when describing their current consumption during the survey. These two questions make it possible to estimate the value households place on the public drinking water service.

The present paper presents only the results of the first analysis, i.e. concerning the willingness to pay for improved access via an individual connection. When the survey was conducted, no public connection program had been launched in the zones surveyed and the aim was more to obtain an initial idea of the willingness to pay together with a feasible price range at a time of institutional reform rather than identifying the populations' adherence to a pre-defined program.

<u>Brief literature review</u>

Two key techniques can be called on to evaluate the value of environmental goods and services: the stated preference techniques where data is provided by individuals' answers to hypothetical questions (creation of a hypothetical market with the implementation of a scenario) and the revealed preferences techniques where the data are derived from observations of the behavior of agents under constraints on a real market. Among the stated-preferences techniques, the contingent valuation method (CVM) is largely used; according to different elicitation techniques, this method involves asking the respondent directly to give his reaction on a hypothetical market for a good or service in order to measure the value they place on this good or service, i.e. a willingness-to-pay (WTP) for such a good or service. There are various elicitation formats: open-ended questions ("how much would you be willing to pay for …?") or the dichotomous choice referendum format ("given a cost of …, would you be in favor of …?" (see Freeman III et al. 2014 for a presentation of the different existing methods).

Numerous studies since the 1990s have used the stated preference techniques, and in particular the CVM, to measure the values of environmental goods and services and other health-related outcomes from projects, policies or regulatory measures in developing countries (Whittington 2010). More recently, studies using the choice experiment technique offer the possibility of testing between several alternatives which differ in terms of attributes and level of attributes in order to determine the value of the attributes of environmental goods and services.

Whittington (2010) recalls that the main criticism levelled at studies using the CVM – although the criticism could be extended to studies using choice experiments – is that it obtains an underestimation of the WTP due to two main biases: the hypothetical bias according to which the respondent finds it difficult to envisage the hypothetical scenario and does not consider his budgetary constraint when adopting a position, and the enumerator bias, similar to the strategic bias, whereby the respondent is inclined to give an answer which pleases the interviewer even if it is not entirely sincere (see Mitchell & Carson (1989), chapter 11 for an identification of all the biases identified). Whittington (2002), who himself participated in several CVM in developing countries on behalf of development agencies, admits that poor-quality studies are often caused by time and money restrictions encountered by researchers when preparing and conducting surveys.

Despite these criticisms, the stated preference techniques have been regularly implemented in developing countries to estimate the value of water services since the 1990s. Depending on their access situation (piped/non-piped) and the context of the study (quality and reliability of water supply), households are asked two types of question: those concerning their WTP in order to improve access to drinking water by changing the access mode (acquire an IC, obtain a safe collective access) and those concerning their WTP to improve the water quality at their usual supply source (for households already piped).

The studies available provide information concerning the declared average WTP values and model WTP with econometric functions to confirm their validity and identify the determinants. Depending on the question asked and the elicitation format, and thus the format of the value of the WTP variable to be explained, the models used differ: 1) limited dependent variable (tobit) models or ordered probit models to model the amount of the bid 2) discrete choice models (logit or probit) to model the probability of accepting the bid.

Examining the studies cited by Whittington (2010) and certain other studies published more recently, focusing on developing countries, the determinants shown to be significant in explaining the WTP are the socio-economic factors of households (income or wealth indicator (+), education of household head (+), head occupation, sex of respondent or household head (+ for woman), mother working status (+), home ownership (+), urban environment, number of people in household earning a wage (+), household believes in community capacity in managing the new system (+)) ;

attributes of the existing source of supply or wastewater disposal system (distance to water source (+), water quality (-), water smell (+), storage, non-connection to the sewer for wastewaters (+), financial cost (+), water collection time (+)) (Briscoe et al. 1990; Whittington et al. 1991; Wang et al. 2010; Perez-Pineda & Quintanilla-Armijo 2013; Briand & Loyal Laré 2013).

Methodology for CV question

After questioning households about their housing, the demographics of the household and the water access (consumption and costs of the primary and secondary means) and before asking them about their WTP, households were asked to assess the quantity they consume (from too little to too much combined with waste) and then to evaluate their current water supply (from very bad to very good). The households already connected were asked to provide a reasonable outlook with regard to the future situation in light of their current access (sometimes very serious and certainly not sustainable in certain GDAs). They were then asked if they would agree to participate in a program, why they refused (if this were the case) and how much they would be willing to invest.

Households without a connection were asked directly if they wished to obtain a connection and then how much they could afford.

With regard to the issue of accepting an individual connection, an iterative bidding game method was adopted rather than an open-ended question as it was necessary to guide the households towards a possible price. The amounts suggested were deliberately greater than the rates currently applied by SONEDE in order to anticipate a surcharge linked to remoteness and lower housing density in the villages not yet connected. Furthermore, we preferred to start with a high price because during the questionnaire test phases, we observed that the households were not receptive to the principle of the increased bidding game whereas they were happy to accept the principle of the decreased bidding game (if the price suggested by the investigator is rejected, a lower price is suggested until an agreement is found). The households were offered the chance to pay in installments over a period of up to eight years with the option of monthly, quarterly or annual installments if the option of an initial payment was rejected. A maximum payment schedule of 8 years is suggested as this corresponds to the commercial policy adopted by SONEDE which enables part of the connection price to be staggered over this period.

The two sub “distribution method” (GDA-piped et non-piped) and “geographic” (8 villages) samples are nevertheless too small to be tested with different initial values as Whittington (2002) to avoid an anchoring bias. The format of the WTP valuation question (closed-ended Yes/No) corresponds to the evaluation scenario of a public good recommended by (Whittington 2002) while the wording of the question was discussed in advance with the economists at SONEDE, who have already participated in or coordinated such WTP studies in the Tunisian context.

When designing the survey instrument, training the operators and conducting the surveys in the field, particular attention was paid to reducing the risks inherent to this method as far as possible in light of the high time constraint and the budget available to conduct this survey.
We found that the households had no difficulty in stepping inside the hypothetical scenario. With regard to GDA-piped households, the issue is that of the willingness to pay to renovate and ensure the sustainability of an existing connection in order to satisfy the conditions for a convenient service. Non-piped households are fully aware of individual connections at home as SONEDE is already present in rural areas. To guarantee the most possible sincere answers from the households, the households were clearly informed from the outset of the aim of the research and that the team was fully independent of both SONEDE and the Ministry of Agriculture (CRDA), and of any development agency, NGO or public donor, in order to avoid the households viewing the survey as a communication exercise in favor of a specific pre-financed development program and thus adapting their answers accordingly. Furthermore, we know that between the first meeting of the local institutional stakeholders at the beginning of the research (during the initial exploratory visits on site) and the start of the survey itself in each village, the heads of the village had informed the population of the investigators' arrival and the objectives of the research activity.
Debriefing questions were asked throughout the CV relating to the initial acceptance of the individual connection (yes/no), acceptance of payment (yes/no, how much) and an explanation of the reasons for acceptance or rejection. We nevertheless attempted to reduce the hypothetical bias concerning the budget constraint. An effective methodology involves questioning households with regard to their capacity to cover this expense by asking them how they intend to finance it and if, *in fine*, they are sure that they can pay for it on a regular basis (ICEA 2013).

Results of the households' interviews

The research team on site found that households understood the questions clearly and provided serious answers. Generally speaking, households proved to be very willing subjects and interested in participating in this survey.
GDA-piped households were questioned about their situation of consumption at the individual consumption. With regard to their assessment of their current consumption, 74% of households believe that they are average consumers compared to their neighbors while 23% believe they are small consumers and another 3% consider themselves large consumers. Finally, 58% deem the quantity consumed to be appropriate to their needs while 42% feel it is low or controlled. With regard to water price at the individual connection, 40% declared that water bill accounts for a large share of their budget, 31% that it is acceptable and a significant proportion of households (22%) claim that the weight of water bill is negligible.

In fine, households in this sub-sample show a very bad opinion of water service: 68% of households rate the service in a very negative manner (24% for bad and 44% for very bad service), 20% deem it to be acceptable and only 12% give a positive assessment (12% for good and 0% for very good service). When asked to provide a reasonable outlook for the future, 44% of households believed that the situation would remain unchanged, 15% expected their IC to be regularized and 21% believed that SONEDE would sooner or later resume service.

With regard to the non-piped households, 67% evaluate the quantity consumed to be appropriate to their needs while 30% feel it is low or controlled and only 3% believes they waste water. *In fine*, 11% of households rate the service in a positive manner, 27% evaluates it as acceptable and 47% give a negative assessment (26% for bad and 35% for very bad service).

The survey analysis reveals that 12% of GDA-piped households declared that they did not want to contribute to financing the renovation work. Two households justified this by the fact that they had already paid for the connection (a connection, even an illicit one, requires the intervention of a plumber and equipment), while the others cited insufficient financial capacity. We do not believe that these answers represent zero protest responses which should be removed from the analysis. On the contrary, a category corresponding to zero WTP is introduced into the model. As for non-piped households, 14% of non-piped announced zero bids included one household refusing the principle of having its own individual connection (considered as a zero-protest response), while the others assert poverty and lack of affordability (kept in the analysis).

The average bids were 950 TND for GDA-piped households and 655 TND for non-piped households while the median values were respectively 960 and 500 TND. 44% of non-pied households and 58% of GDA-piped households accept to pay more than 500 TND. As shown on the distribution graph of the variable WTP below, the non-piped households are more volunteer to pay to improve their water access than GDA-piped households.

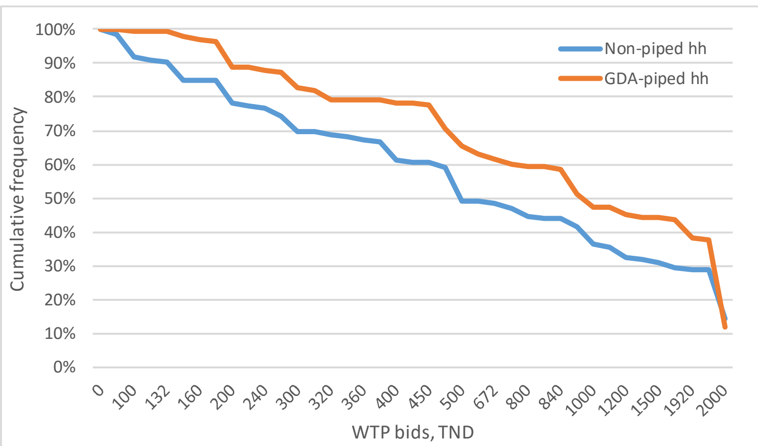

Figure 2: WTP bids, cumulative frequency

Table 4 presents the average WTP amounts declared per locality for the two sub-samples.

Environment	Locality	Mean WTP	Part of zero-bids	Part of bids >500	Number of surveyed households
GDA-piped households	Hessiene	920	0%	54%	13
	Mtayria	654	7%	43%	30
	Rmadhniya	756	27%	45%	33
	Ruissat	1207	7%	78%	27
	Zbara	1234	10%	73%	30
	Sub-Total	**950**	**12%**	**58%**	**133**
Non-piped households	Cheri-chira	363	0%	33%	30
	Draa Tamar	538	21%	33%	33
	Ganzhour	1071	0%	63%	30
	Hessiene	1129	17%	76%	17
	Mrahyia	0	100%	0%	1
	Rmadhniya	200	0%	0%	1
	Ruissat	300	33%	33%	3
	Zoomit	380	35%	29%	17
	Sub-Total	**655**	**14%**	**44%**	**132**

Table 4 Mean WTP by locality

Willingness-to-pay regression

Choice model and explanatory variables

We model the variations in WTP bids as a function of income, other household characteristics, and water supply attributes. This is a consumer behavior model where the WTP function is derived from a utility function. By conducting this regression, we attempt to confirm the reliability of the WTP bids and to enhance our knowledge of the determinants of the willingness to pay.

We use an ordered probit model adapted to the format of our explanatory variable, taking the form of an ordered discrete choice series (yes/no when the investigator announces the price). This method also enables us to incorporate the outliers in the price ranges instead of excluding them.

The vector of explanatory variables includes:

- income variables: the quarterly household income including work income and any rent, social aid or other money net transfers (continuous quantitative) and a dummy to indicate the frequency for receiving income (1 if 90% of income is received on a daily basis),
- household socio-economic variables: household size and composition (share of children in the total number of members), a dummy to indicate the household education (1 if he went to high school or further), a dummy to notify if the household is a farmer (1 if yes),

- water supply attributes and price perception when individual connection is the main source: a dummy to notify the appreciation of the respondent towards the evolution of the water supply over the last 20 years (1 if the situation have improved to his mind), the length of water shortage (continuous quantitative), the appreciation of the service (1 if acceptable or good), a dummy to indicate if the respondent evaluates the water price as being high compared to other services (1 if yes) and another to indicate if the household declares that water bill accounts for a large share of its budget,
- water supply attributes when collective access is the main source: the length of water shortage (continuous quantitative), the frequency for fetching water (continuous quantitative), the appreciation of the consumption level (1 is to low compared with needs),
- alternative supply attributes: a dummy to indicate if the alternative source is located more than 100 km away, the number of people usually available for fetching the water, the means of transporting the water (1 if the household use a carriage drawn by animal or a motor vehicle to transport water) and the status of the alternative source (private or not),
- a dummy variable indicating if the household express optimism concerning the future of water resources and the service in the long term (1 if yes).

As can be seen in the literature, the *income* and *education* variables are expected to influence positively the WTP. Our economic intuition concerning the variable *daily* is that households with revenues received on a daily basis are less keen to pay due to a more unstable financial situation. The variable *weight.bill,* if positive*,* would also represent a low affordability of household which may impact negatively the WTP.

The composition of the household (*children*) could also influence the decision because a family with children of any age might be more sensitive to the need for water at home for health reasons, in particular that of the children (an individual connection avoids problems related to water storage).

In light of the importance of agricultural activities in the region and the constant problems observed concerning the availability of agricultural water, we suppose that *farmers* are more aware of the issue and more willing to pay for the service that the other socio-professional categories.

For GDA-piped households, we have also introduced several variables describing the perception of the individual connection service quality. We might expect that the poor perception of the current service (*shortage, price.high, evolution.good, service.good, quantity.low*) pushes households to make higher bids as they have a strong desire to improve the service and escape this situation. We nevertheless wish to put forward another hypothesis founded on all the information and data collected beyond the survey database. We assume that households that are dissatisfied with the current service could, on the contrary, lead to lower or even zero bids as the households no longer have faith in the current system. For these households, lower bids would appear to express a lack of confidence in the system and the future following the disappointment of the "individual connection revolution". Contrary to the expectations of the households which undertook illicit connections, the proliferation of uncontrolled individual connections has exacerbated the water supply situation as it has interrupted the existing service and pushed households to fall back on unreliable alternative sources

Table 5 summarizes mean values for explanatory variables (calculated on the reduced sub-samples excluded zero-protest responses).

Variable notation	**Variable description**	Unit	**GDA-piped households n= 133** Mean	Std dev.	**Non-piped households n=132** Mean	Std dev.
income	Household income	TND per quarter	1867	1150	1905	1280
daily	More than 90% of daily income	(Yes=1)	38%		46%	
children	Share of children in the total members	%	0.27		0.26	
edu.high	Went to high school or further	Yes=1	19%		26%	
farmer	Household head is a farmer	Yes=1	34%		15%	
culture	The cultural reason is justifying the desire to obtain an individual connection	Yes=1			22%	
optimism	The household express optimism for the future	Yes=1	71%		44%	
Main water access mode (individual connection for GDA-piped, and other for non-piped households						
shortage	Cumulative hours of shortage	Hours	2147	2718	294	934
price.high	Evaluate the price as high	Yes=1	46%			
evolution.good	Evaluate the situation of water supply over the last 20 years as better	Yes=1	38%		26%	
service.good	Evaluate the service as good	Yes = 1	32%		38%	
weight.bill	Estimate the bill represent a large share of the budget	Yes = 1	40%			
frequency	Water collection frequency in summer	nb of times per day			1.8	1.5
quantity.low	The quantity consumed is low compared with the needs	Yes = 1	35%		31%	
Alternative water access mode						
alt.distance	The alternative source >1000m	Yes=1	31%			
alt.people.fetch	Number of people available to fetch water (zero if no alternative source)	nb inhab.	1.0		0.9	
alt.transp	Use a carriage drawn by animal or a motor vehicle to go to the source	Yes=1	53%		76%	
alt.private	The alternative source is private	Yes=1	44%		16%	

Table 5 Descriptive statistics (unweighted data)

For GDA-piped households, we have also introduced several variables describing the perception of the individual connection service quality. We might expect that the poor perception of the current service (*shortage, price.high, evolution.good, service.good, quantity.low*) pushes households to make higher bids as they have a strong desire to improve the service and escape this situation. We nevertheless wish to put forward another hypothesis founded on all the information and data collected beyond the survey database. We assume that households that are dissatisfied with the current service could, on the contrary, lead to lower or even zero bids as the households no longer have faith in the current system. For these households, lower bids would appear to express a lack of confidence in the system and the future following the disappointment of the "individual connection revolution". Contrary to the expectations of the households which undertook illicit connections, the proliferation of uncontrolled individual connections has exacerbated the water supply situation as it has interrupted the existing service and pushed households to fall back on unreliable alternative sources.

On the contrary, for non-piped households, we suppose that the poor perception of the current situation promotes a desire to improve supply conditions and thus drives positively the WTP.

Since a large part of the surveyed GDA-piped household are suffering a lot of water shortage and are used to adopt a routine using alternative water access modes, we would like to confirm that the attributes of these used alternative sources of supply affect the desire to acquire an individual connection and thus the WTP. We suppose that the more it is difficult to get water from alternative sources in the event of service interruptions, the more the WTP will be high. We represent the difficulty of accessing alternative sources by several parameters including: distance, the number of people in the household available to fetch water and the means of transport (*alt.distance, alt.people.fetch, alt.transp*). The unique variable relative to alternative supply used for non-piped household is the nature of the source (*alt.private*) since other alternative supply attributes are not available for all the non-piped households. Indeed, some households never encounter long interruption service and use their own water storage in case of shortage. We anticipate that is the alternative source is private, water supply is less easy since there is a financial cost and/or a social cost to bear (when you need to ask your neighbors, negotiate with a water vendor for instance) and it should encourage WTP.

Then, we introduced a variable measuring household *optimism* concerning the future of water resources and the service in the long term. To this end, we transformed an open question into a binary variable (optimistic/not optimistic). We considered as optimistic the households thinking the SONEDE will take over the service in their locality. It is our belief that households which are optimistic for the future with regard to water resources and the service provided would be more inclined to contribute to improving the service.

Finally, we suppose that households which cited cultural aspects (*culture*) as the reason underlying their strong desire for an individual connection would be more willing to pay for a connection. During one interview, the head of a GDA of a remote village in the mountains stated that the cultural and religious reasons were often cited by household heads as the reason for wanting a connection. This variable may represent remote locations where also the desire not to be forgotten by development projects is high. In those locations, according to enumerators, households were exceptionally volunteers to be questioned and tell about their situation.

Results

The absence of co-linearity between the explanatory variables was tested previously with the Variance Inflation Factor (all values ≤ 2). We run a Brand test of the parallel regression assumption to confirm that ordinal logistic regression is appropriate[5].

The results of the two ordered models are shown in Table 6. Coefficients have no economic direct interpretation and the economic interpretation focuses on marginal effects of regressors on the expected value of *y* (see in Appendix).

We observe that the two models show several factors influencing the WTP expressed by households in this study. Sometimes, coefficients are not significant but almost they are correctly signed.

As expected, income plays a very significant role in determining the WTP: higher the income, higher is the WTP. When the GDA-piped household already express a low affordability to support the water bill, the WTP decreases. However, the fact to receive income on a daily basis is not significant, neither are the composition of the household and the education of the household head. As expected, when the head is a farmer, he is more sensitive to water issue and express a higher WTP.

Our assumption about the evaluation of the service is confirmed: for GDA-households, dissatisfaction about water service (at the individual connection) impacts negatively the WTP (we suggest it is due to a loss of confidence in the system and its previous management) whereas it impacts positively the WTP for non-piped households. Additionally, WTP bid goes up when GDA-piped households expressed optimism for the future service.

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[5] For each of the variable, we fit the model under the null hypothesis of parallel effects (the regular ordered logit) and under the alternative hypothesis of non-parallel effects (the effect of the variable to vary across categories) and compare these models with the likelihood ratio test. From the p-value superior to the significant threshold of 5%, our, we saw that the null hypothesis cannot be rejected and there was no evidence of non-parallel slopes in this case.

As expected, the attributes of the alternative source used plays a role in determining WTP: when the source is located more than 1000m away from home for GDA-piped households, and when its access is private, households accepted higher WTP bids.

Finally, when the cultural reason is justifying to obtain a private connection, indicating more remote areas, the WTP is significantly higher.

We can conclude results indicate that WTP bids are correlated with variables suggested by economic theory and economic sense: it gives more confidence in the expressed WTP bids which reveal information about household's preferences and are not random numbers (Whittington et al. 1991).

		GDA-piped households n=133			**Non-piped households n=132**		
Variable	**Variable description**	**Coef.**	**Std errors**	**P>z [1]**	**Coef.**	**Std errors**	**P>z [1]**
income	**Household income (TND), in log**	**0.444**	**0.219**	**0.043***			
	Household income [975,1650) TND				0.010	0.305	0.973
	Household income [1650,2451) TND				0.273	0.357	0.443
	Household income [2451,9000] TND				**0.770**	**0.345**	**0.025 ***
weight.bill	**Water bill is a large share of the budget**	**-0.765**	**0.255**	**0.003****			
daily	More than 90% of daily income (Yes=1)	-0.171	0.246	0.487	0.315	0.244	0.195
children	Share of children in the total members	0.357	0.408	0.382	0.056	0.436	0.897
edu.high	Went to high school or further (Yes=1)	0.378	0.284	0.183	0.317	0.234	0.174
farmer	**Household head is a farmer (Yes=1)**	**0.582**	**0.256**	**0.023***	**0.743**	**0.302**	**0.014 ***
culture	**The cultural reason justifies the desire to be individually connected**				**1.705**	**0.302**	**0.000*****
optimism	**Expression of optimism for the future**	**0.595**	**0.235**	**0.011***	**0.355**	**0.219**	**0.105**
Main water access mode (individual connection for GDA-piped, and other for non-piped households							
shortage	Cumulative hours of shortage (hours)	0.054	0.061	0.373	-0.032	0.045	0.478
price.high	**Evaluate the price as high (Yes=1)**	**-0.584**	**0.236**	**0.014***			
evolution.good	The situation over the last 20 years as better	-0.289	0.270	0.284			
service.good	**The service is good**	**0.475**	**0.281**	**0.091.**			
frequency	Water collection frequency in summer				-0.073	0.078	0.347
quantity.low	**Consumption low compared with needs**				**1.433**	**0.273**	**0.000 *****
Alternative water access mode							
alt.distance	**The alternative source >1000m (Yes=1)**	**0.565**	**0.277**	**0.041***			
alt.people.fetch	Number of people available to fetch water	-0.128	0.127	0.314			
alt.transp	Use carriage with animal or a motor vehicle	-0.352	0.243	0.146			
alt.private	**The alternative source is private**				**0.638**	**0.326**	**0.050 .**
	Residual Deviance	286.2			324.9		
	McFadden's pseudo-R^2	0.1915			0.2141		

[1] Here ***, **, *, and . denote statistical significance at 0.01%, 1%, 5% and 10%, respectively

Table 6 Results of ordered probit models for WP bids estimate

6. Conclusion and policy implications

This study defines the general framework of southern Mediterranean countries facing the overexploitation and depletion of their water resources as well as an intensification of water demand due to population growth and changing water access mode and water use in rural areas. Specifically, in Tunisia, water demand is changing and water consumption will increase in a near future due to several reasons: the 2011 revolution has revealed the unequal and unacceptable dual access to piped-water; population is growing; and global warming will expand and lengthen droughts in future.
In this quite complex context, it is becoming crucial to improve the knowledge of water demand determinants which may help in determining and implementing the necessary regulatory tools, including water pricing. Another important issue, which may also be answered by improved knowledge of water demand, concerns complementary tools to forecast water demand as well as wastewater volumes. In the Kairouan sub-region where groundwater is close to the ground, sanitation is also becoming a crucial issue for local authorities in rural areas: with a shift from collective water access mode to individual connection on the property, water consumption is constantly increasing and sustainable sanitation systems must be introduced to avoid polluting groundwater. Finally, in the very particular post-revolutionary context where expectations about water connection are very high in rural areas, one key question is also to inform about willingness-to-pay acceptance to get individually connected from households.
The results show a very low price elasticity at -0.1 for GDA-piped households and even null sensitivity for non-piped. It can be explained by the very low consumption level which tend to incompressible water needs. Income elasticity states at +0.3 for GDA-piped households and is not significant for non-piped households. Indeed, in non-piped rural areas, water demand seems to be essentially driven by variables characterizing the physical accessibility to water source. A similar analysis conducted on the SONEDE area reveals sensitivity of -0.5 and +0.1 respectively for price and income (Favre & Montginoul 2016). Such information about differentiated price and income elasticities between areas and systems and other drivers of water demand. It is an important finding because it means that differentiated instruments could be more efficient and may better target particular groups of consumers. Such a result could reopen the debate on the national pricing principle held since the creation of the SONEDE as well as the issue of tariff averaging system which has been questioned by Touzi et al. (2010) but which could be the subject of further analysis.

Then, households expressed a quite good but mixed willingness-to-pay to get an individual connection, depending of the original distribution system, alternatives modes of supply and socio-economic attributes. Among non-piped households, 44% expressed a willingness-to-pay higher than 500 TDN against 58% among GDA-piped households. This acceptance can be already considered as a quite good signal for institutional actors who are presently designing the water supply rural framework, as it is prior any communication campaign.

The analyses of WTP determinants show that it will be necessary to inform and to reassure households on the future management systems, new or rehabilitated. Households who expressed dissatisfaction about the current GDA network are more reticent than other to accept high bids. In some places where the service is very deteriorated and need urgent works, the CRDA has recently faced strong refusal from households to pay the 500 TND that were requested for a program hold by the CRDA for network rehabilitation (including servicing of illegal existing individual connections). On the other hand, the Regional Direction of Kairouan which regularly runs network extension projects in the rural area don't encounter particular difficulty in recovering payment of the connection. It seems that the fundamental difference holds firstly to the fact that households generally have great confidence in the SONEDE which won good recognition in served localities in the region (Favre & Montginoul 2016) whereas the image of the GDA management system suffers from these past and current difficulties. Secondly, the SONEDE provides payment facilities (up to 8 years for a limited part of the amount) allowing greater affordability. It seems that it will be necessary to reflect on these two points: household awareness to restore confidence in the community-management systems and instilling more accountability for their behavior (stopping with water thefts, refusal to pay the bills, etc.) but also, in a second time, reflecting on allowing payment in instalments for the neediest households.

7. Appendix: Marginal effects of WTP regression

		GDA-piped households n=133				Non-piped households n=132				
Variable notation	**Variable description**	effect. [0,1]	effect. (1,480]	effect. (480,1500]	effect. (1500,2000]	effect. [0,1]	effect. (1,200]	effect. (200,750]	effect. (750,1500]	effect. (1500,2000]
Number of households		16	39	35	43	19	29	41	21	22
Income	**log**	-0.048	-0.119	0.019	0.148					
	[975,1650) TND					-0.001	-0.002	0.000	0.002	0.002
	[1650,2451) TND					-0.029	-0.060	-0.005	0.050	0.045
	[2451,9000] TND					-0.071	-0.159	-0.047	0.129	0.147
weight.bill	**Bill is a large share of budget**	0.096	0.192	-0.048	-0.240					
daily	More than 90% of daily income (Yes=1)	0.019	0.046	-0.009	-0.056	-0.037	-0.069	0.001	0.058	0.048
children	Share of children	-0.039	-0.096	0.015	0.119	-0.007	-0.012	0.000	0.010	0.008
edu.high	Went to high school or further	-0.034	-0.101	0.001	0.134	-0.034	-0.069	-0.007	0.058	0.052
farmer	**Household head is a farmer**	-0.056	-0.154	0.008	0.202	-0.060	-0.150	-0.064	0.120	0.154
culture	**Cultural reason**					-0.117	-0.279	-0.206	0.171	0.432
optimism	**Optimism for the future**	-0.080	-0.149	0.048	0.181	-0.041	-0.078	0.000	0.065	0.054
Main water access mode										
shortage	Cumulative hours of shortage	-0.006	-0.015	0.002	0.018	0.004	0.007	0.000	-0.006	-0.005
price.high	**Evaluate the price as high (Yes=1)**	0.067	0.152	-0.029	-0.190					
evolution.good	The situation over the last 20 years as better	0.033	0.077	-0.016	-0.094					
service.good	**The service is good**	-0.045	-0.127	0.007	0.165	-0.012	-0.023	0.000	0.020	0.016
frequency	Water collection frequency in summer					0.009	0.016	-0.001	-0.014	-0.011
quantity.low	**Quantity consumed is low compared with the needs**					-0.128	-0.264	-0.110	0.198	0.305
Alternative water access mode										
alt.distance	**The alternative source >1000m**	-0.052	-0.150	0.004	0.198					
alt.people.fetch	Number of people available to fetch water	0.014	0.034	-0.006	-0.043					
alt.transp	Carriage with animal or a motor vehicle	0.038	0.094	-0.014	-0.118					
alt.private	**The source is private**					-0.555	-0.132	-0.047	0.107	0.126

[1] Here ***, **, *, and . denote statistical significance at 0.01%, 1%, 5% and 10%, respectively

Table 7 Marginal effects - Ordered probit models for WP bids estimate

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