Household willingness to contribute financially to improve rural water access in Tunisia

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Abstract

Within the context of Tunisia's ongoing water sector reforms that aim to develop a long-term strategy to ensure the reliability and sustainability of supply in rural areas, this study aims to examine the willingness of households individually connected to locally managed water networks to contribute financially towards the rehabilitation of an existing water supply system and the implementation of a new water supply system managed by the national operator. The findings indicate that households are willing to pay 22% of the per-household costs of rehabilitation of an existing locally managed network, representing the equivalent of 2.2 times the interprofessional guaranteed minimum wage (SMIG), and 16% of the per-household costs of setting up a new water supply network managed by the national operator, 3.4 times the SMIG. The findings also indicate that the willingness to contribute financially towards the implementation of a given project is influenced by household characteristics and the state of the water supply within a household.

Keywords*: Contingent valuation, Drinking water access, Tunisia, Water distribution networks, Willingness to pay*

Introduction

The UN defines 'safely managed' drinking water as water from an improved source that is accessible on the premises, available when needed, and free from fecal and priority chemical contamination. Between 2015 and 2022, there was a noticeable increase in the global coverage of safely managed drinking water. Data on indicator 6.1.1, which tracks safely managed drinking water in 142 countries representing 51% of the global population, show that global coverage rose from 69% in 2015 to 73% in 2022. The progress in rural areas is more marked, with coverage increasing from 56% to 62%, while urban areas saw a slight increase from 80% to 81% (WHO/UNICEF, 2023).

Despite these gains, the pace of progress remains insufficient to meet the Sustainable Development Goal (SDG) 6.1 target of universal access by 2030. To achieve universal coverage by 2030, the current rate of progress must be accelerated dramatically. Specifically, a six-fold increase in the current rate of improvement is required globally. This challenge is even more pronounced in low-income countries, where the

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rate of progress would need to increase 20-fold to meet the targets (WHO/UNICEF, 2023).

The water sectors in various developing countries have distinct histories and challenges shaped by each country's unique policy and institutional settings. Nevertheless, they share some common pressing issues. These governments face a complex issue that requires resolution, as they are confronted with both internal social and political demands for improved water services, as well as increasing international pressure for the same. However, they have limited flexibility to take action and fulfill these demands due to the growing constraints on available water resources and finances (Favre, 2021).

Two primary factors hinder progress towards equality in access to water between densely inhabited urban areas and sparsely populated rural areas, and impede efforts to connect the unconnected population to water supply networks: the necessity to effectively manage the use of water resources that are becoming increasingly scarce, and the challenge of financing infrastructure in a sustainable manner (Favre, 2021).

Over several decades, Tunisia has made extensive investments to enhance access to drinking water in rural areas, resulting in a significant increase in individual connections to water supply systems. However, the water sector has to face a number of constraints, in particular: a physical constraint associated with the scarcity of water, the deterioration of infrastructure and difficulties in financing projects to rehabilitate and extend the hydraulic networks that remain entirely funded by the Ministry of Agriculture, Water Resources, and Fisheries (MARHP) in rural areas. These constraints are likely to affect the sustainability of drinking water supply and thus threaten to achieve the sustainable development goal of "Ensuring universal access to water and sanitation (WASH)".

Several studies have noted the lack of information regarding household preferences as an impediment to implementing improved water services in developing nations (Vásquez, 2014; Whittington *et al*., 1990). In response to the need for preference information, contingent valuation (CV) studies have been employed to elicit willingness to pay (WTP) for improved water services in developing countries (Vásquez, 2014; Whittington, 1998). CV surveys have proven useful for collecting information on preferences for public goods and services in these contexts (Whittington, 1998). Consequently, CV findings have been used to inform policy decisions in various ways, including cost-benefit analyses and setting price rates for improved services (Vásquez *et al*., 2009). An improved understanding of WTP can help assess the economic feasibility of system improvements, design price structures, and inform affordability and equity policies in order to implement efficient, sustainable, and cost-recoverable water projects (Vásquez, 2014; Vásquez & Espaillat, 2016).

Considering the evidence that households are willing to pay significant amounts for safe drinking water (Vásquez *et al*., 2009) and within the context of Tunisia's ongoing water sector reforms, the present study aims to examine the willingness of households individually connected to networks managed by Water Associations known as Agricultural Development Groups to financially contribute towards 1) the rehabilitation of an existing water supply system and 2) the implementation of a new water supply system managed by the national water utility, using the survey-based contingent valuation method. The objective of these financial contributions is to help improve damaged rural water supply systems, which largely depend on limited government and external funding. The rest of the paper is organized as follows: The next section provides an overview of the water sector in Tunisia. The subsequent section describes the study area, study design, sampling methodology, and data analysis strategy. The following section presents the survey results including willingness-to-pay (WTP) estimates for the proposed projects and examines the determinants that influenced respondents' WTP. The final sections discuss the findings, highlight some policy implications, and provide conclusions.

1. An Overview of Tunisia's Water Sector: Past Achievements, Current Challenges, Future Directions, and Rural Realities

In recent decades, Tunisia has made considerable efforts to improve water coverage rates throughout the country (Favre, 2021). Urban areas attained a 100% coverage rate well before 2021, whereas rural areas recorded a 95% coverage rate in 2021 (MARHP, 2021). The MARHP has set a target to achieve universal access to water (SDG 6.1) by 2030. Despite significant progress, Tunisia continues to face challenges due to water scarcity, irregular supply, overexploitation, increasing demand, and suboptimal regulation mechanisms. These challenges are anticipated to worsen with the impacts of climate change, potentially hindering the goal of universal access (MARHP, 2021).

Recognizing the critical need for qualitative changes in public water policy, the Tunisian government has identified two key areas for intervention: demand management by reducing specific consumption and improving network efficiency, and supply optimization by investing in large-scale water transfer and desalination plants. Since 2019, the government has been working on a strategic plan titled "L'élaboration de la vision et de la stratégie du secteur de l'eau à l'horizon 2050 pour la Tunisie" ("Development of the Vision and Strategy for the Water Sector in Tunisia by 2050"). This forward-looking strategy aims to renovate a significant portion of the water network by 2050 and introduce smart meters to enhance system efficiency. The overarching goal is to develop a secure and efficient potable water supply system that meets international standards and ensures that rural water services are equivalent to those in urban areas (MARHP, 2021).

Additionally, the Tunisian government is adopting a water-energy-food nexus approach within this strategy to facilitate a transition towards sustainability. Studies, such as those by Scardigno *et al*. (2017), highlight that the interconnections between water and food security, particularly in the Middle East and North Africa (MENA) region, are likely to face increasing risks due to growing demand, resource constraints, and the escalating impacts of climate change. By integrating this nexus approach, Tunisia aims to mitigate these risks and promote sustainable resource management (MARHP, 2021).

In Tunisia, the rural potable water sector is characterized by the coexistence of two distinct management systems: the distribution of water in highly populated rural areas is ensured by the National Company for the Exploitation and Distribution of Water (SONEDE). Water supply in sparsely populated areas is locally managed by Water Associations called Agricultural Development Groups (GDAs) with technical support from the Regional Agricultural Development Offices (CRDAs), the regional departments of the Ministry of Agriculture, Water Resources, and Fisheries, the actor responsible for implementing rural water projects.

The SONEDE water bills include either water or water plus sewerage. All users subscribing to the water service provided by the SONEDE are subject to paying a sewer fee in areas with collective sanitation services provided by the National Sanitation Office (ONAS) and receive a unique quarterly bill based on their water consumption. The SONEDE nationally applies a binomial tariff structure composed of fixed and variable parts. The variable part is a combined Inclining Rate Tariff (IRT) whereby the tariff depends on the water consumption level and total consumption is charged at the rate of the top band and Increasing Block Tariff (IBT) whereby initial blocks of consumption are charged at a lower rate than the additional blocks of consumption for users charged for water and collective sanitation, and an IRT for users only charged for water. In addition to the variable part, both operators apply a fixed charge for every user based on the water meter diameter (the larger the diameter, the higher the charge) for the SONEDE and on the water consumption levels for the ONAS (Favre & Montginoul, 2018).

Water pricing structures vary greatly among Agricultural Development Groups due to the diverse nature of their systems. Households connected to GDA water networks do not have access to the collective sanitation service and rely on non-collective sanitation solutions.

2. Methods

2.1. *Selection of the Study Area*

This study was conducted in Mornag, a municipality located in the governorate of Ben Arous in Tunisia. The study area was selected due to its rural nature, the range of population densities within it—from sparsely populated areas to highly populated rural areas (we used the term 'highly populated rural areas' due to the lack of a clear definition and boundaries for peri-urban areas), and the coexistence of the two management systems. The selection of the study area and the Contingent Valuation (CV) survey were preceded by a series of semi-structured interviews. Their purpose was to understand the complexity of providing water services in rural areas, to identify the diversity of actors involved, to determine the characteristics of the selected study area, and to select localities. The interviews were conducted with experts from the General Directorate of Rural Engineering and Water Use belonging to the Ministry of Agriculture, Water Resources, and Fisheries, and the Regional Agricultural Development Office of Ben Arous.

Eleven localities of varying densities were chosen. A locality refers to a territorial area served by its own water distribution network managed by a GDA. This network can be either independent or connected to another hydraulic network. The initial plan was to survey 30 households randomly selected in each locality, except in some localities that had fewer than 30 households, particularly in low-density areas. In practice, surveying ceased once repetitive responses about access to alternative water sources and coping strategies started being detected, signifying that further surveying would not yield new valuable insights.

2.2. *Questionnaire and Sample*

To achieve the objective of this study, a CV survey was conducted from July to August 2022. The questionnaire was pretested through a pilot survey administered to 20 households. The final survey questionnaire was then administered to 161 respondents who self-identified as having sufficient knowledge about the current water situation within their households.

The questionnaire was divided into two sections. The first section collected information about the socioeconomic characteristics of the respondents/households, the house condition, information related to the piped water including the water bill amount, water consumption, its uses, perception of the piped water quality, issues with water services, and access to alternative water sources. The second section described the scenarios of the CV study.

Prior to conducting face-to-face interviews that lasted between 20 and 80 minutes, informed consent was obtained from all participants.

3. Study Design

Limited government and external funding have slowed progress on improving damaged rural water supply systems. The CV scenarios are based on the assumption that, to address this issue and potentially accelerate the government's efforts to improve the rural water sector, requiring households to contribute financially towards the rehabilitation of an existing water supply system or the implementation of a new water supply system in their neighborhood may be worthwhile.

Two household-cost-sharing scenarios were initially designed to assess the willingness of households to contribute financially towards rehabilitating an existing water supply system or implementing a new water supply system in their neighborhood and to determine whether the same households would be willing to pay for the resulting service on a regular basis once the water supply system is renewed or installed, assuming that the project would be implemented with or without the households' contributions. The CV scenarios were designed to provide information about the terms and conditions of both conceptually interrelated components (Whittington, 1998), enabling respondents to make informed choices.

This approach was similar to the approaches employed by Adams and Vásquez (2019) in Ghana and Favre (2021) in Tunisia. Specifically, Favre (2021) asked respondents two independent questions. The first question examined willingness to pay for a sustainable individual connection to the SONEDE network for non-piped households. The second question assessed willingness to pay regular bills for water consumption in order to maintain service quality in the future. Favre (2021) justified the use of this approach as the two stated WTP did not have the same occurrence, nor the same payment vehicle. By presenting the questions separately, respondents were able to distinguish between the two different commitments and provide independent WTP responses.

The initial amounts proposed to households corresponded to the per-household costs of a hydraulic project (either rehabilitation of an existing GDA network or setting up a SONEDE network) and were based on estimates provided by the Ministry of Agriculture, Water Resources and Fisheries. These estimates are presented to funders to offer a general financial appraisal of a project in the conceptual stage, and are calibrated based on the specific nature and setting of the envisaged project. The initial amounts served as a starting point for evaluating households' willingness to pay for the proposed infrastructure projects. The study proposed one or two scenarios, depending on the current condition of the network (Table 1). The amounts were converted from Tunisian dinars to US dollars using the October 2022 exchange rate of 1 TND = 0.31 USD.

Table 1 - Summary of the study design.

Target (Scenario)	*Statement*	*Elicitation format*	*Rationale*
Households connected to a network managed by a GDA presenting anomalies (Scenario 1)	1. Would you be willing to pay 4000 TND to participate in the renewal of the existing network managed by the GDA in order to benefit from an improved service consisting of a continuous supply of good quality water?	Using a descending bidding game method with increments of 500 TND (157 USD)	To investigate willingness to financially contribute towards the rehabilitation of the existing infrastructure allowing the improvement of the GDA's performance
	2. Once the service improved, would you be willing to pay 2 TND/m^3 consumed? *(Abandoned question)*	Using a descending bidding game method with increments of 0.1 TND (0.03 USD) until reaching the current applied charge per cubic meter	
Households connected to a network managed by a GDA (Scenario 2)	1. Would you be willing to pay 8000 TND to participate in the implementation of a new network managed by the SONEDE.	Using a descending bidding game method with increments of 500 TND (157 USD)	To investigate willingness to financially contribute towards the implementation of a new water supply system managed by the SONEDE.
	2. Once connected to the SONEDE's network, would you be willing to pay 22 TND per quarter for a water consumption of 20 m^3? *(Abandoned question)*	Using an ascending bidding game method with increments of 5 TND (1.57 USD)	

3.1. *Scenario proposed to households connected to a GDA network presenting anomalies (Scenario 1)*

The first scenario targeted households connected to a network managed by a GDA, presenting anomalies resulting from poor infrastructure that led to frequent interruptions, or caused by its dependency on the SONEDE for its water supply in cases where the GDA receives its supply from the SONEDE. The sample size for this scenario was 111 households connected to 8 different GDA networks. The initial scenario consisted of two questions. Households would have been first asked if they would be willing to pay 4000 TND (1256 USD) to participate in the renewal of the existing network managed by the GDA in order to benefit from an improved service consisting of a continuous supply of good quality water. This question was presented in a bidding game format. Households would then have been asked if they would be willing to pay 2 TND (0.63 USD) per cubic meter consumed once the service is improved/the project is completed. The second question was also presented in a bidding game format. These two questions were preceded by an introductory sentence developed to help households understand the scenario. The introductory sentence mentioned that the government needs funding in order to accelerate efforts to improve the water sector and repair damaged systems, and that financial contributions from households could help (Table 1).

Upon further reflection, only the first question was kept because it would be difficult to accurately determine the real costs per cubic meter for each locality before the projects are actually completed, due to the multiple location-specific variables that would impact those costs, including: the current costs of water per cubic meter, hydrological factors like reliance on groundwater and associated energy costs, and geographical factors like spatial distribution. Additionally, we knew that households familiar with the service are conscious that it requires payment on a regular basis and that improvements imply higher charges.

The rationale for studying this scenario was to investigate the willingness to financially contribute towards the rehabilitation of the existing network while maintaining the same management system.

3.2. *Scenario proposed to all households connected to a GDA network (Scenario 2)*

The second scenario targeted all households connected to a network managed by a GDA, regardless of whether the current network presented anomalies or was well managed. The sample size for this scenario was 161 households connected to 11 different GDA networks. The initial scenario included two questions presented in bidding game format. Households would have been first asked if they would be willing to pay 8000 TND (2512 USD) to participate in the implementation of a new network managed by the SONEDE. They would then have been asked if once connected to the SONEDE's network, they would be willing to pay 22 TND (6.91 USD) per quarter, a fee based on a projection made by the utility, allowing the costs to be recovered over the next three years for a water consumption of 20 m^3. This volume corresponds to a consumption equal to 50 liters/person/day, a volume allowing reaching the intermediate access level, to meet the needs related to direct consumption, personal hygiene and basic domestic uses and to maintain health problems at a low level (Howard & Bartram, 2003). These two questions were preceded by an introductory sentence developed to help households understand the scenario. The introductory sentence mentioned that the government needs funding to accelerate efforts to improve the water sector and set up a new water supply system allowing future intervention by the SONEDE in the neighborhood, and that financial contributions from households could help (Table 1).

The second question was eliminated because we expected that households familiar with simpler payment modes would have difficulties relating charges to the volume of water consumed.

The rationale for studying this scenario was to investigate the willingness to financially contribute towards the implementation of a new water supply system managed by the SONEDE.

4. Dealing with biases

This section outlines the potential sources of bias and ways in which we sought to mitigate these biases.

4.1. *Hypothetical bias*

Hypothetical bias refers to the tendency of respondents in contingent valuation surveys to overestimate their willingness to pay for public goods (Carson, 2012). Several steps were taken to mitigate this bias in respondents' willingness to pay estimates. First, the survey scenarios were not presented as purely hypothetical. Avoiding telling respondents repeatedly that the scenarios are hypothetical helps avoid inflating their willingness to pay, as studies have found that scenarios presented as purely hypothetical tend to overestimate willingness to pay (Carson, 2012). Making the scenarios seem more realistic by not emphasizing their hypothetical nature encourages respondents to think more carefully about their actual willingness to pay (Carson, 2012). Furthermore, we assumed that for public services in developing countries, the issue of hypothetical bias tends to be less significant as respondents are more familiar with the service characteristics and less likely to misunderstand the scenario (Whittington *et al*., 1990), and that households are familiar with the water service provided, based on the fact that they are already connected to the network. Familiarity with the good or service has been shown to reduce the hypothetical bias in CV studies. Studies show that the greater the familiarity of respondents with a good or service, the less the hypothetical bias in their willingness to pay estimates (Mitchell and Carson, 1989). WTP estimates for public goods tend to be free from hypothetical bias (Whittington *et al*., 1990).

4.2. *Strategic bias*

Strategic bias is a type of respondent bias that can be problematic in contingent valuation (CV) studies. It occurs when respondents deliberately misstate their true willingness to pay (WTP) for strategic reasons. There are two forms of strategic behavior: free-riding and over-pledging (Mitchell and Carson, 1989).

Free-riding occurs when an individual understates their true WTP for a public good on the expectation that others will pay enough for that good; therefore, they do not have to pay. On the other hand, over-pledging occurs when an individual overstates their WTP. They do this, assuming their stated WTP will influence the provision of the good, under the belief that it will not actually be used for future pricing policy (Venkatachalam, 2004).

Adopting recommendations (Mitchell and Carson, 1989) to mitigate strategic bias could improve the likelihood of useful WTP estimates. Telling respondents that a larger number of people are being interviewed can give them the impression that their stated WTP will not meaningfully influence the outcome. Giving respondents the impression that the good may not be provided if WTP is understated may discourage the understatement of true willingness to pay. Using payment vehicles that remind respondents of their budget constraints can help discourage the overestimation of the true WTP.

4.3. *Starting-Point Bias*

We assumed that if we choose an open-ended elicitation format to ask households about their potential contribution without mentioning the real costs of the projects, households will tend to answer by giving a willingness to pay value that could be significantly lower than the real costs of the projects. Starting point bias arises when the initial bid (posited by the interviewer) influences respondents' final bids (Boyle *et al*., 1985). The choice of the descending bidding game approach allowed us to mention the estimated project costs as a starting point, thus avoiding this type of bias.

4.4. *Scope Test*

A scope test examines whether respondents are willing to pay more for a good that is larger in scope, either in terms of quality or quantity (Carson *et al*., 2001). This study did not conduct scope tests to examine how willingness to pay estimates varied with different water volumes. There were three key reasons for not considering the scope effects. First, statistical scope insensitivity is insufficient to fully invalidate the results of the contingent valuation study. Second, with the small sample size, the study would lack adequate statistical power to detect a scope effect if one was present. Third, it is challenging, if not impossible, to statistically observe a scope effect when eliciting WTP for high levels of environmental goods (Lopes & Kipperberg, 2020). The effect of increased volumes of water on willingness to pay estimates was not considered by fixing the volume parameter, corresponding to one cubic meter, and 20 cubic meters per quarter for the first and second scenarios, respectively.

4.5. *Metric bias*

Metric bias occurs when respondents assign a value to the good based on a different metric or scale, typically one that is less precise than the metric intended by the researcher designing the contingent valuation study (Mitchell and Carson, 1989). To anticipate potential metric bias, we compared 1 cubic meter to a 1000-liter water container size. By comparing 1 cubic meter to the volume of a container commonly used for water storage in the study area, we aimed to help respondents conceptualize the volume amount so that their valuation would be based on the defined measurement scale.

4.6. *Sequencing*

The sequencing effect, also known as question order bias, may occur when the order in which questions are asked can influence respondents' willingness to pay values (Cummings *et al*., 1986; Mitchell and Carson, 1989). We expected that this type of bias may occur for the group of households who received the first and second scenarios. We hypothesized that for the second scenario described, respondents may use the starting value provided for the first scenario as an anchoring point, even though the costs for the implementation of a new water supply system managed by the SONEDE are actually higher.

To investigate this potential sequencing effect and its derived anchoring effect, we planned to split respondents into two equal groups and change the order of the scenarios, asking about one scenario first for one group and the other scenario first for the second group. Comparing the values between the groups would indicate if respondents anchor on the initial starting value provided. This test was not conducted. Instead, we clearly communicated to respondents the differences in costs and standards between the two projects described in an attempt to minimize this type of bias.

5. Dealing with protest responses

In contingent valuation studies, some respondents indicate that they are unwilling to pay any monetary amount for a public good due to disagreements with the procedural elements of the contingent valuation method, such as the perceived unfairness of having to pay more. These types of responses are problematic for benefit-cost analysis, as they may reflect that a person values the good in question but is unwilling to pay for it. From an economic perspective, such responses, considered either suspect or inappropriate, cannot be included in the benefit-cost analysis because they do not represent the "true" economic values. Responses indicating an unwillingness to pay any monetary amount for a public good due to certain circumstances, such as an inability to afford it, are not treated as a protest response because it is accepted in economics that money is not a perfect indicator of utility since levels of wealth vary among individuals (Jorgensen *et al*., 1999). The authors acknowledged that it was difficult to develop an effective strategy that would convince respondents to put aside their impressions of the role of government in providing public goods, issues about equity between social groups, considerations about their own efficacy in influencing outcomes related to public good decision-making, or their evaluations of funding public good changes through additional household contributions. For the present study, all responses connected to elements of the hypothetical scenario were regarded as protests and were eliminated from the analysis.

6. Models

For each scenario, a multiple regression model was constructed with a set of independent variables related to household characteristics and variables related to piped water and its use. Regression analysis tests whether the willingness of households to contribute financially towards rehabilitating an existing water supply system or implementing a new water supply system in their neighborhood can be explained by variables suggested by economic theory, such as income and perception of water quality, as suggested by Whittington *et al*. (1990). The statistical analyses were conducted using the STATA15 software.

7. Variables

A transformation to the dependent variable representing bid amounts was applied prior to statistical modeling, with positive bids log-transformed while zero bid values remained unchanged. Independent variables were divided into two catego-

Table 2 - Independent variables.

Variable	*Description*	*Expected sign*	*Rationale*
related to household characteristics			
Minimum monthly household income	= ln (Minimum monthly household income)	+	The literature discusses various methods for addressing missing income data in CV surveys, including the use of proxies. For example, due to many respondents not reporting their actual income in a survey examining the public's willingness to pay for changes in national forest management conducted by Czajkowski *et al*. (2017), the variable used as an income proxy was the question "How would you rate the financial situation of your household?" measured on 5-point Likert scale where 1 represented a "Bad" financial situation and 5 represented a "Good" financial situation. This approach produced interpretable results. The present study examined incomes of households using a self-reported measure of minimum monthly income required to meet basic needs. Respondents were asked to provide an estimate of the income level needed to support a basic standard of living, rather than reporting their actual income. This approach, used as an alternative to collect income data from respondents, was needed because the length of the survey questionnaire did not allow the inclusion of detailed income questions. It is assumed that households with higher minimum monthly incomes will tend to have higher actual monthly incomes. As a consequence, households with higher minimum monthly household income levels may have greater willingness to contribute to the costs of the proposed project.
Household size		+	Larger households are likely to have higher demand and thus may express higher willingness to pay for the project being studied. A study by Vásquez (2014) found a positive empirical relationship between household size and willingness to pay for improved water services. However, economic theory suggests the effect of household size can be negative because freely disposable income decreases with the number of household members (Ahlheim & Schneider, 2013).

Variable	*Description*	*Expected sign*	*Rationale*
related to piped water, its use, and coping practices with service unreliability			
Using alternative sources requiring fetching water on a regular basis	=1 Yes; =0 No	The sign for this variable cannot be determined with certainty a priori.	A regular reliance on alternative sources due to issues with irregular supply and/or poor tap water quality for households connected to a piped water network may influence WTP in two different ways. Possibility 1: Households relying on alternative water sources will have lower WTP for the proposed project, because these alternative sources are freely available and potentially reduce water bills and expenditures on water in general. Possibility 2: Households relying on alternative water sources will have higher WTP for the proposed project, because it is significantly time-consuming to fetch water from these sources and could impact their ability to generate income through other activities.
Subjective perception of the current piped water quality	=1 Good or rather good; = 0 Otherwise	-	Households may pay less to improve the service if current water quality is good.
Storing piped water (summer 2022)	=1 Yes ; =0 No	+	Households using small plastic containers with a total volume not exceeding 1000 liters may be more impacted by irregular supply. This may reflect a response mechanism to cope with frequent or long interruptions, and thus they may be more willing to pay for improvements. The survey questions clearly differentiated between and distinctly asked about both piped water storage and rainwater storage. This expectation is based on this finding "Households that adopt coping measures to deal with unreliable water services, like treating and storing piped water at home, are also likely to support a project that aimed to ensure reliable supplies of safe drinking water because an improved system would reduce the need for implementing those coping measures" (Vásquez & Espaillat, 2016).
related to piped water, its use, and coping practices with service unreliability			

ries (Table 2): those related to household and individual characteristics, and those related to piped water and its use. Table 2 presents the rationale for including each variable.

8. Results

8.1. Semi-structured interviews: Key findings

The semi-structured interviews allowed us to gather information about the per-inhabitant costs of a hydraulic project, either for the rehabilitation of an existing GDA network or the establishment of a SONEDE network. According to the experts we consulted, the SONEDE is responsible for expanding an existing network within a limited geographical area, while the MARHP is responsible for setting up new water supply networks that will be managed by local communities or connecting an entire locality to the SONEDE network. The experts also informed us that although the GDAs operate under the same regulatory framework, they

Variable	*Description*	*Expected sign*	*Rationale*
Household water supply situation (summer 2022)	1 = Continuous supply 2 = More than 12 hours of continuous supply per day 3 = Less than 12 hours of continuous supply per day 4 = Few hours to one full day of continuous supply each 2 to 3 days 5 = Few hours to one full day of continuous supply each 3 to 4 days 6 = Few hours to one full day of continuous supply each 4 to 5 days 7 = Few hours to one full day of continuous supply each 5 to 6 days 8 = Few hours to one full day of continuous supply per week 9 = Few hours to one full day of continuous supply each period greater than 7 days	+	The questionnaire included a question about water interruptions over the past 1-2 months (summer 2022). Responses were classified on an ordered scale reflecting the severity and frequency of reported interruptions, with higher values indicating more severe lack of water supply. The response classification provided a measure of the intermittent nature of the water supply by evaluating the duration of supply periods and intervals between them. Households reporting more days without water would express greater willingness to pay for the proposed project. This rationale is based on the results of a study conducted by Vásquez and Espaillat (2016), which demonstrated that WTP varied depending on the level of system reliability, measured by the number of days in a week with service interruptions. Households who experienced service interruptions every day of the week were willing to pay more than those without service interruptions.

differ significantly in terms of the number of connected households, water sources (either connected to the national operator's network, independently managing groundwater/surface water sources, or relying on a combination of sources), and pricing structures. After explaining the study's purpose, the CRDA provided us with a list of localities within the study area that would be suitable targets for the survey. Eleven localities with varying densities were chosen from a total of approximately 25 to capture the full range of diversity among the GDAs. Among these, 5 are connected to the national operator network, 3 rely on locally-sourced groundwater, 1 is connected to another GDA network, 1 relies on a combination of a connection to the national operator network and a locally-based groundwater source, and 1 relies on surface water. The number of households connected to these networks varies significantly, ranging from approximately 10 to roughly 600, and the length of the networks ranges from 1.5 to 20 kilometers.

8.2. *Protest responses and non-responses*

The protest responses are shown in Table 3, with a distinction between Scenarios 1 and 2.

For Scenario 1, 21 households indicated that they were not willing to pay for the project, justifying their zero WTP response with one or two of the reasons mentioned in Table 3. These responses were regarded as protest responses. The most frequently cited reason was demanding the intervention of the SONEDE in the neighborhood (Table 3). The two responses indicating gender-related issues (inability to make a household decision as a woman) were regarded as non-responses and were eliminated from the analysis.

For Scenario 2, 32 households indicated that they were not willing to pay for the project, justifying their zero WTP response with one or two of the reasons mentioned in Table 3. The most frequently cited reason was a preference for GDA and willing to contribute to its improvement (Table 3). 4 responses indicating gender-related issues (inability to make a household decision as a woman) were

Table 3 - Protest responses.

Reason/Pair of reasons	*Number of responses*	*Percentage*
Scenario 1		
Demanding the intervention of the SONEDE in the neighborhood	11	52%
Inadequate management mode of the GDA	5	24%
Demanding the intervention of the SONEDE in the neighborhood *AND* inadequate management mode of the GDA	5	24%
	21	*100%*
Proportion of non-protest responses	*19%*	
Scenario 2		
Lack of trust in the reliability of the project	1	3%
The service is a fundamental right and must be guaranteed to all individuals	1	3%
Preference for GDA and willing to contribute to its improvement	20	63%
Future service provided by the SONEDE perceived to be expensive or of poor quality AND preference for GDA and willing to contribute to its improvement	3	9%
Lack of trust in the reliability of the project AND future service provided by the SONEDE perceived to be expensive or of poor quality	1	3%
Refusal of the intervention of the SONEDE in the neighborhood AND Preference for GDA and willing to contribute to its improvement	5	16%
Lack of trust in the reliability of the project AND preference for GDA and willing to contribute to its improvement	1	3%
	32	*100%*
Proportion of non-protest responses	*20%*	

regarded as non-responses and eliminated from the analysis. In their study investigating WTP for the improvement of tap water quality in Greece, Polyzou *et al*. (2011) considered the belief that there is no need to improve water quality as a true-zero response. Based on this consideration, we classified the response "Being satisfied with the management by the GDA" and the belief that there are no issues with the service provided (24 responses) as true zeros. The reason "A preference for GDA but unwilling to contribute to its improvement" (1 response) was also regarded as a true zero response. The appropriate handling of protest zeros depends on the specific survey context being examined. Our study classified responses indicating a "lack of trust in the reliability of the project" as protest zeros, whereas Vásquez and Espaillat (2016) included the answer to "if the respondent believed that the proposed project could be implemented" as a predictor in their statistical models. Their results showed that those believing implementation was feasible were more likely to vote in favor of the proposed project.

The proportion of non-protest responses was 19% for Scenario 1 and 20% for Scenario 2 (Table 3). These percentages are probably due to the fact that implementing infrastructure has long been, and continues to be, the responsibility of public institutions. Consequently, the rural community has come to take this for granted.

All protest responses for scenario 1 were directly related to the management mode itself, with refusal to contribute indicating a rejection of the service provider. This suggests that intrinsic factors, such as a lack of trust in the management community of a GDA, influence the respondents' decisions. Additionally, it may indicate that water prices per cubic meter set by the GDAs are perceived to be higher than those set by the SONEDE. We are not asserting that GDA services are more expensive, as it is difficult to compare due to the tariff structure applied by the SONEDE.

97% of protest responses for scenario 2 (excluding the response that the service is a fundamental right and must be guaranteed to all

Table 4 - Willingness-to-pay estimates.

	Observations	*Mean WTP*	*Standard deviation*
Scenario 1	88	864	1240
Scenario 2	125	1318	2380

individuals) were directly related to the service provider. This indicates a refusal of the national operator's services or reveals that these respondents have greater trust in the GDA. In the context of a reform where the government is actively seeking an alternative to the GDA management system, the preference for the service provider itself must be considered.

After removing the protest responses and non-responses from the dataset, the mean amount that households connected to a GDA network presenting anomalies were willing to financially contribute towards the rehabilitation of the existing infrastructure was 864 TND (268 USD), representing 22% of the per-household costs of the project. The mean amount that households connected to a GDA network were willing to financially contribute towards the implementation of a new water supply system managed by the SONEDE was 1318 TND (409 USD), representing 16% of the per-household costs of the project. The contribution for the per-household costs of rehabilitating an existing locally managed network represented the equivalent of 2.2 times the interprofessional guaranteed minimum wage (SMIG) fixed under the terms of Decree n° 2022-769 of 19 October 2022 at 390.7 TND (122.7 USD) (40-hour work week regime), and the contribution for the per-household costs of setting up a new water supply network managed by the national operator represented 3.4 times the SMIG.

8.3. *Estimation results*

As expected, the coefficients of *Minimum monthly household income* were positive and statistically significant at the 1% level in Model 1 referring to the scenario proposed to households connected to a GDA network presenting anomalies, and at the 10% level in Model 2 referring to the scenario proposed to all households connected to a GDA network (Table 5). Our findings are in line with the economic theory. Significant income effects on willingness to pay for improved water services are consistently found in the literature. Vásquez and Espaillat (2016) showed that willingness to pay for reliable supplies of safe potable water increases with monthly household income levels. The coefficients of *Household size* were statistically insignificant in both models (Table 5). A study by Favre (2021) also found the coefficient for household size to be statistically insignificant in the statistical model assessing willingness to pay for sustainable individual connections to the SONEDE network among non-piped households.

Households storing tap water to cope with sudden interruptions in tap water supply or to prevent such disruptions use a variety of small plastic containers to store water at home (Figure 1). Only a relatively small percentage of the surveyed households used devices with large storage capacities. We hypothesized that households storing piped water in plastic containers, with a total volume not exceeding 1000 liters, due to unreliable water supply, would report a higher willingness to pay for the proposed projects. However, the empirical analysis found the coefficients of *Storing piped water* to be negative and nonsignificant (Table 5). Vásquez and Espaillat (2016) also reported insignificant effects of water storage on households' willingness to pay for reliable supplies of safe potable water in Guatemala.

The results of Model 2 require careful consideration. A household's willingness to pay for the implementation of a new water supply system managed by the national water utility may depend on whether they are currently experiencing water interruptions or perceive the water quality as poor. The sample of households surveyed included two groups - those connected to GDAs that were well-managed with no reported interruptions, and those connected to GDAs that experienced frequent interruptions.

Figure 1 - Two examples of a set of small plastic containers used to store piped water at home.

(Source: Authors, July 2022).

This heterogeneity could explain the significantly higher mean value of *Subjective perception of the current piped water quality* (t= 2.3520, p = 0.0196) and the significantly lower mean value of *Household water supply situation* (t= -3.7520, p = 0.0002) compared to the group of the first scenario (Table 5).

The coefficients of *Household water supply situation* were positive and statistically significant at the 10% level in both Model 1 and Model 2. This finding suggests that respondents reporting more days without water express greater willingness to contribute financially to the rehabilitation of the existing infrastructure/the implementation of a new water supply system managed by the SONEDE.

In Model 1, the coefficient of *Subjective perception of the current piped water quality* meets the expected negative sign but does not reach statistical significance. The absence of a statistically significant effect may be partially explained by 75% of the post-protest sample abstaining entirely from drinking tap water. In Model 2, the coefficient of this variable was statistically significant at the 10% level. Respondents reporting good quality of tap water were less willing to contribute financially to the implementation of a new water supply system managed by the SONEDE.

For Scenario 2, the research sought to examine location-specific effects by using dummy variables for each locality/GDA, as per the method of Basani *et al*. (2008). However, the sample size prevented this intended methodology. Instead, the "*Current status of the GDA*" variable was generated to represent whether interruptions were occurring or not at the locality level. This variable considered the overall system performance rather than solely the surveyed households' responses within that system (the status quo service provision within a locality). Even if some households connected to a given GDA did not report interruptions, issues could still persist across the entire infrastructure.

For scenario 2, a simple linear regression was conducted using this "*Current status of the GDA*" variable as a predictor. It achieved statistical significance in predicting the dependent variable (β = 1.900, t = 2.79, p < 0.01). A t-test was used to compare the mean willingness to pay for the implementation of a new water supply system managed by the SONEDE between two groups of households: those connected to well-managed GDAs with no reported interruptions and those connected to GDAs experiencing frequent interruptions. The results revealed that households belonging to the second group had a significantly higher mean willingness to pay for the implementation of a new water supply system managed by the SONEDE (t= -2.1010, p = 0.0377). Households currently not experiencing interruptions or water quality issues were still willing to pay for this project. This suggests that individuals perceive value in a centralized system as a more reliable long-term option, even if the GDA to which they are connected is currently well managed.

Table 5 - Linear regression: variables influencing households' WTP.

Variables	*Model 1 (Scenario1)*	*Mean variable*	*Model 2 (Scenario2)*	*Mean variable*
Ln (Minimum monthly household income)	*2.134****	7.11	*1.147**	7.02
	(2.81)		(1.74)	
Household size	0.197	4.33	0.0280	4.69
	(0.81)		(0.15)	
Using alternatives sources requiring fetching water on a regular basis	-1.322	0.11	0.982	0.20
	(-1.23)		(1.16)	
Subjective perception of the current piped water quality	-0.921	0.20	-1.484*	0.35
	(-1.04)		(-1.91)	
Household water supply situation (summer 2022)	*0.333**	4.44	*0.285**	3.33
	(1.75)		(1.81)	
Storing piped water (summer 2022)	-0.736	0.67	-0.672	0.59
	(-0.99)		(-1.00)	
(constant)	*-12.43***	-	-4.559	-
	(-2.34)	-	(-0.97)	-
R^2	0.1959	-	0.1431	-
Observations	85	-	121	-

** p <0.1, ** p <0.05, *** p <0.01. Numbers in parentheses are corresponding t-statistics*

9. Discussion

The following discussion presents an analysis of the strengths and limitations of the present study, shedding light on its contributions to the field while acknowledging areas that require additional investigation.

The strengths lie in the robustness of the research design. In order to come up with effective recommendations, the scenarios were designed to reflect current realities and issues in the existing management systems and were aligned with the Tunisian government's future reform strategy and goals for the long-term development of the water sector in rural Tunisia. The per-household costs of a hydraulic project (either rehabilitating an existing GDA network or setting up a SONEDE network) were not arbitrarily assigned or theoretical. They were based on an understanding of the Tunisian rural context and estimates provided by the Ministry of Agriculture, Water Resources and Fisheries. Furthermore, the survey methodology was carefully designed to minimize potential sources of bias that could influence the results. We addressed hypothetical, strategic, question order, starting-point, and metric biases by leveraging respondents' familiarity with the service, clearly communicating about the study, providing detailed scenario descriptions, carefully selecting the elicitation format, and simplifying complex metrics into more understandable terms. We believe that our approach to addressing these biases was effective.

Moreover, our rigorous approach to identifying and excluding protest responses and non-responses not only yielded more accurate and precise mean willingness-to-pay results for each scenario but also offered valuable insights into respondents' preferences regarding the service provider or management model. Nearly all protest responses pertained specifically to the management model, indicating that respondents' decisions are influenced by factors like: 1) intrinsic factors, such as distrust in the management community of a GDA when declining to contribute to rehabilitating an existing network, or strong trust in the local management system when rejecting potential intervention by the national operator; and 2) perceptions about water prices.

While actual income data, which require the use of multiple indices and a great knowledge from households of the real value of household income, would have strengthened the findings, the data of minimum monthly income required to meet basic needs proved useful as it provided readily usable financial information. Using minimum monthly household income as an indicator rather than actual income, though less precise, yielded significant results in the regression analyses.

Additionally, the variables for the regression analysis were carefully selected. For instance, the variable "Frequency of purchasing water from distributing vendors" that explains an informal activity consisting of selling raw water door-to-door using pickups, initially appeared to be a promising predictor of WTP. A positive relationship was expected between reporting the purchase of water from distributing vendors and higher WTP for improvements. However, further research revealed that distributing vendors served some areas but not others. The decision of a household to buy or not buy water from distributing vendors is influenced by both preferences and the existence of informal activities within the area where the surveyed household is located. The variable was then removed from the analysis. Using an alternative water source once throughout the entire summer, after a long interruption, for example, does not reflect the same level of water insecurity as relying on it regularly. To define regular usage, the criterion was using an alternative source at least once a week during the summer of 2022. Thus, households using an alternative source at least once a week were deemed to rely on it regularly, indicating a higher degree of water insecurity.

The results could guide and inform the government's strategy by providing insight into households' potential to make financial contributions for either rehabilitating an existing GDA network or setting up a SONEDE network. This could help make projects less dependent on conventional funding channels and, thus, rely less on government budgets and external donors.

One limitation of our study was that the two household-cost-sharing scenarios designed to assess the willingness of households to contribute financially towards a hydraulic project and determine their willingness to pay for the resulting service were weakened by: 1) the difficulty in accurately determining the real costs per cubic meter for each locality before the projects are actually completed, due to the multiple-location specific variables that impact those costs, including: the current costs of water per cubic meter, hydrological factors like reliance on groundwater and associated energy costs, and geographical factors like spatial distribution; 2) the fact that the future tariff rates applied by the SONEDE are centrally predefined and applied nationally and the difficulties for households to attribute a value for the future service due to their familiarity with simpler payment modes and understand the relationship between the charges and the volume of water consumed.

We intended to divide the group of households that received both the first and second scenarios into two equal groups. The purpose was to examine the sequencing effect and its resulting anchoring effect by altering the order of the scenarios. However, we were unable to conduct this test as the sample size we had planned initially was insufficient for this purpose.

We should have considered the current situations of the GDAs as an important factor in determining the households' WTP, for example, households connected to a well-managed GDA network are likely to be less willing to pay for the second project than households connected to a GDA presenting anomalies or households living close to an area connected to the SONEDE network are likely willing to pay more than those connected to a GDA network that is completely separate from the SONEDE network. When developing our study, we should have accounted for additional factors beyond what was included. Specifically, considering the concept of social capital, as defined and discussed by Polyzou *et al*. (2011), could have strengthened our analysis. Considering these parameters has been shown to help researchers improve the hypothetical scenarios they present and further understand the reasons leading to citizens' monetary valuations (Polyzou *et al*., 2011).

In abandoning the GDA management system, the government should consider several points, including the current situations of the GDAs (e.g., the GDA being connected to the SONEDE or relying on groundwater), the feasibility of a project in a given area that depends on several factors like the proximity to the SONEDE network and the costs of implementing a network that depend on geography, and the (in) availability and (in) reliability of groundwater.

10. Conclusion

Tunisia is currently facing several challenges related to water, including scarcity, overexploitation, and an increase in demand, which are exacerbated by inadequate regulatory measures. These difficulties are projected to worsen because of climate change and deteriorating infrastructure, making it difficult to achieve universal access to water by 2030. Despite this, little attention has been paid to exploring households' willingness to financially contribute towards the rehabilitation of an existing water supply system or the implementation of a new water supply project of households connected to locally managed networks, which could help to improve infrastructure conditions and, in turn, increase access to water. These two aspects were studied using a contingent valuation study, which is commonly employed in developing countries to assess the value of water services and has proven to be a valuable source of information regarding the benefits associated with improved access to potable water (Van Houtven *et al*., 2017; Whittington, 2010). While the main objective was to study the willingness to contribute to the realization of a hydraulic project and its determinants, the reasons for unwillingness to contribute emerged as a valuable outcome, warranting further investigation. The presence of non-protest responses is likely due to: 1) the fact that developing water systems has historically been, and remains, the responsibility of governmental authorities. Respondents expressed unwillingness to financially contribute to these projects, viewing the provision and maintenance of such infrastructure as the government's role rather than that of local residents; and 2) a preference for or against a particular service provider. The results showed that households are nearly willing to contribute to 22% of the per-household costs of rehabilitation of an existing GDA network and 16% of the per-household costs of setting up a SONEDE network. These average amounts appear to be lower than the estimated per-household costs typically presented to funders for a general financial appraisal of a project at the conceptual stage. However, it is important to note that these estimations often overlook the unique aspects of each project. In some cases, these percentages of contributions may be sufficient to fully cover the real per-household costs once all relevant factors specific to a given project are properly considered. In the context of reforms aiming, among other goals, to develop a secure and efficient potable water supply system that meets international standards and to ensure that rural water services are equivalent to those in urban areas, the exclusive responsibility of governmental authorities for infrastructure works should be revised, giving serious thought to the contribution of households.

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