G-Eau Working Paper/Rapport de Recherche No.17

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Kammarti, O.; Montginoul, M. and Habaieb, H. 2025. Emergence of the informal drinking water market in rural Tunisia: reasons and related issues G-EAU Working Paper/Rapport de Recherche No.17. Montpellier, France. http://www.g-eau.net/

Les Auteurs:

Ons Kammarti

National Agronomic Institute of Tunisia (INAT), University of Carthage, 43 Avenue Charles Nicolle, 1082, Tunis, Tunisia; INRAE UMR G-EAU, Montpellier University, 361 rue JF Breton - BP 5095 - 34196 Montpellier Cedex 5, France; kammarti.ons@gmail.com

Marielle Montginoul

INRAE UMR G-EAU, Montpellier University, 361 rue JF Breton - BP 5095 - 34196 Montpellier Cedex 5, France; marielle.montginoul@inrae.fr

Hamadi Habaieb

National Agronomic Institute of Tunisia (INAT), University of Carthage, 43 Avenue Charles Nicolle, 1082, Tunis, Tunisia; habaieb.hamadi@yahoo.fr

Abstract:

Is the underperformance of the formal providers the reason behind the emergence of distributing vendors in rural areas in Tunisia? The present study aimed to empirically answer this question and address the question of whether distributing vendors are committing any form of injustice, using a mixed-method research design.

The analysis found that two key factors determined the incentives for distributing vendors to serve a given area/cluster: frequent/long interruptions and the poor quality of formally provided water. However, it demonstrated that only the poor quality of formally provided water led customers to buy water from informal vendors. No evidence of vendors committing any form of injustice was found. A series of recommendations was provided that are worth investigating in depth, given the potential of this sector to help ensure sustainable services.

Keywords: Informal market, distributing vendors, drinking water, justice, SDG6: Clean water and sanitation, Tunisia

TABLE OF CONTENT

1 Introduction

Originally conceptualized as economic activities occurring outside of government oversight and regulation (Wutich et al., 2016), some studies have framed informality as a "mode of urbanization" whereby governments tolerate and even support unofficial service provision for underserved communities (Roy, 2005). Once viewed as an undesirable solution, informal service delivery is increasingly seen as a necessary and acceptable form of providing services that policymakers and planners must recognize and intentionally address in their decision-making and planning, despite the challenges involved in fully incorporating informal actors and systems into formal planning processes and structures (Roy, 2005).

Several studies have highlighted the involvement of the private sector through public-private partnerships (PPPs) to improve the development of sustainable water and sanitation systems. Influenced by donors, governments are increasingly turning to PPP arrangements for the provision of services due to various factors, including a lack of capacity within government institutions to deliver a reasonable level of service or to improve service quality and limited financing capabilities within public utilities to meet rising needs. One challenge in addressing private sector participation is the diversity of potential actors, ranging from multinational companies to medium- and small-sized private enterprises, which may be involved at either the national or the subnational level (Sohail & Cotton, 2001). In addition, there is an informal private sector including water vendors (Sohail & Cotton, 2001), also known as small water enterprises (SWEs), that retail water to citizens without access to formal supply networks (McGranaham et al., 2006). Research has found that SWEs, despite operating outside formal regulations and legal recognition, actively help fill the service gaps left by both public and formal private utilities (McGranaham et al., 2006). Water vending, although recognized as important, has not received much attention in the academic literature (Wutich et al., 2016). Water resource professionals have tended to ignore water vending partly because its existence is viewed as a sign that water supply institutions are failing to provide adequate services. While this assessment is often accurate, water vending deserves study for the following reasons: (1) Water vending will likely continue in developing countries for the foreseeable future due to severe shortages of capital for piped systems or wells and hand pumps. (2) In some situations, water vending may prove to be an appropriate technology for a community given its current economic and social conditions, because vending systems are usually very reliable. (3) Learning about water vending practices, especially related to costs and charges, could provide useful information to inform water supply planning decisions. (4) It may be possible to improve the quality and cost efficiency of water-vending systems (Whittington et al. 1989).

This study examines informal water activities. Despite Tunisia's considerable efforts over recent decades to improve water coverage nationwide (Favre, 2021), and the achievement of a 95% coverage rate in rural areas by 2021 (MARHP, 2021), informality persists. The determinants driving the emergence of the informal water activity, existing in rural Tunisia in the form of distributing vendors (McGranaham et al., 2006; Whittington et al., 1989; Wutich et al., 2016) selling raw water door-to-door using water tanker trucks with different capacities or pickups equipped with tankers, have not been empirically established. In a context in which all households have individual connections to piped water networks, this study aims then to 1) examine the factors related to formal water services that influence the emergence of an informal water market, using a mixed-method research design, and 2) provide policy recommendations, including formalizing this activity, to help address the water crisis that impacts the sustainability of drinking water supply and thus threatens to achieve the United Nations Sustainable Development Goal 6 of ensuring clean water and sanitation (SGD6).

This paper begins with a literature review, followed by the formulation of the research questions. Descriptions of water services in rural Tunisia are provided along with a detailed explanation of the mixed-method research design used. The results are then presented, leading to a discussion that contextualizes the findings. The paper concludes by summarizing key findings and offering recommendations tailored to the study area.

2 Literature review

2.1 Informal water providers

Informal water providers operate independently of formal utility systems through various means (Kjellén et al., 2006) to supply communities unserved by formal water providers (Bakker, 2003), commonly defined as public utilities or private companies contracted by governments to distribute networked water (Allen et al., 2006). The literature typically portrays formal and informal providers as occupying separate spheres, with informal provision seen as complementing the formal provision by serving areas and communities that utilities fail to reach (Cheng, 2014).

Small-scale informal providers, whom governments might view as profiteers exploiting consumers and failing to meet both technological and quality standards (Cain, 2018), occupy various roles such as filling gaps in areas with intermittent formal services, pioneering provision in unserved areas, or acting as sub-concessionaires buying water from utilities and reselling where access is limited (Kariuki & Schwartz, 2005; Sima & Elimelech, 2011).

Comparative studies have identified multiple attributes held in common by informal providers (Sima & Elimelech, 2011). Informal providers are commonly defined by their small size, independence, private ownership, lack of regulation by formal actors (Cheng, 2014; Venkatachalam, 2015), lack of access to subsidies (Opryszko et al., 2009) and good financial efficiency (Sima & Elimelech, 2011). They emerge spontaneously to meet demand when supply is limited (Venkatachalam, 2015), and are able to respond quickly and specifically to changing needs as their operations are not reliant on permanent infrastructure (Sima & Elimelech, 2011) and their associated capital costs, when incurred, are significantly lower than piped networks (Whittington et al., 1989). Informal services are also highly responsive to consumer demands (McGranaham et al., 2006; Sima & Elimelech, 2011) due to their dependence on direct customer interactions, loyalty, and competition (Sima & Elimelech, 2011), and can provide important local employment while using simple, community-maintainable technologies (Whittington et al., 1989).

2.2 Issues surrounding Informal vendors

The price of water sold by informal providers has undeniably been shown to be high (Kjellén et al., 2006). Questions about the quality of water sold informally, including its microbial and chemical content, remain largely unresolved (Garrick et al., 2019; Wutich et al., 2016). Several studies have found that water sold by informal providers presents significant risks to human health and is generally of lower quality than formally supplied water, especially in situations where water sources are unregulated or the equipment used to transport water is unsanitary (Wutich et al., 2016). These aspects are related to distributive injustice, defined as the unfairness of outcomes (Cohen-Charash & Spector, 2001; Wutich et al., 2013).

There are two additional forms of injustice, procedural and interactional. Procedural injustice is defined as the unfairness of the process by which allocations are determined (Cohen-Charash & Spector, 2001), whereas interactional injustice is defined as the unfairness in interpersonal interactions and treatment (Wutich et al., 2013). Procedural injustices in informal water vending may arise from “unfair political rules or economic norms governing water availability and allocation” (Wutich et al., 2016). Unjust figures identified by clients include vendors refusing to sell water, inconsistent and irregular delivery times, and vendors cutting off hard-to-reach or impoverished communities (Wutich et al., 2016). Interactional injustices involve “interpersonal experiences of discrimination, mistreatment, or denial of water service”. When “regular customer” relationships between clients and informal vendors do not exist or are violated, such as by refusing to establish such relationships or punishing regular clients for purchasing water from other vendors, these actions result in interactional injustice (Wutich et al., 2016).

2.3 Recognizing informality to alleviate challenges

As suggested by Venkatachalam (2015), until the water supply infrastructure is improved, the government needs to appropriately regulate informal water markets and adequately monitor their functions to help ensure that these markets play a fair supplementary role in meeting water supply needs. Furthermore, formal providers and authorities need to recognize that there should be no dichotomy between the formal sector and informal providers (Cleaver, 2001; Roy, 2005), and through processes of 'institutional bricolage', they must find ways to work with and learn from informal systems and practices.

The concept of institutional bricolage refers to "the piecing together of different institutions, styles of thinking, and social relationships" (Cleaver, 2001). It describes a process by which actors consciously and unconsciously reshape or piece together different arrangements that are available to them (Cleaver, 2001). Institutions are formed through processes of bricolage, according to Cleaver (2001), in which arrangements are adapted for multiple purposes, embedded in networks of social relations, norms and practices, and in which maintaining social consensus and solidarity can be as important as achieving optimal management of resources (Cleaver, 2001; De Koning & Cleaver, 2012). Institutional bricolage is a critical institutional approach that has evolved from questioning strong trust in designing robust institutions, which do not automatically ensure beneficial collective action and optimal resource use, to addressing the challenges of natural resource management and highlighting the direct relationship between policy and local practices (Cleaver, 2001). Cleaver (2002) argues for the need to integrate formal and informal systems of natural resource management in developing countries. Under the institutional bricolage model, social and cultural norms within communities are recognized and valued. These norms are then integrated into the existing institutional systems (Cleaver, 2002).

The study by Liddle et al. (2016) suggests that the formal sector must recognize informality as a reality rather than a failure and find ways to engage with and learn from informal systems and practices. The study found that there are abundant opportunities for the formal sector to adopt practices from the informal sector through the process of "institutional bricolage". When the formal sector fully accepts and embraces local community norms and the potential of informal solutions, simple and cost-effective alternatives can be found. The authors note that the formal sector needs to acknowledge widespread local and informal practices and address the challenges faced regularly by informal users, and that working together, the formal and informal sectors could blend their strengths for improved water access. They recommended that the formal sector in Zambia should offer attention, skills, and governmental support to provide the necessary expertise, education, resources, and motivation for protection. According to the authors, this could allow the formal sector to make a meaningful contribution toward improving water access and quality by upgrading unimproved sources to improved sources, thus providing safe water for all independent of piped networks (Liddle et al., 2016).

Many studies have highlighted the importance of recognizing informal providers as an integral part of water supply systems (Cain, 2018; Schwartz & Sanga, 2010). Due to the discrete and fragmented nature of informal operations, it can be difficult for public institutions to regulate and support them (Mapunda et al., 2018). However, formally acknowledging these small-scale operators could help increase access to water services (Cain, 2018; Schwartz & Sanga, 2010). Developing partnerships between utilities and informal suppliers (Cook et al., 2020; Schwartz & Sanga, 2010) or establishing associations of informal providers (Cain, 2018; Mapunda et al., 2018) allows for: 1) rationalizing a key part of the market (Cain, 2018); 2) guaranteeing access to technical guidance and support from government agencies (Schwartz & Sanga, 2010); 3) setting basic quality standards to ensure minimum service levels (Schwartz & Sanga, 2010; Sima & Elimelech, 2011); 4) improving efficiency and coordination (Mapunda et al., 2018); 5) facilitating access to financial resources (Cook et al., 2020; Mapunda et al., 2018); and 6) preventing price gouging (Sima & Elimelech, 2011).

Legalizing and regulating small-scale water services could help maximize the benefits of competition in the sector, while mitigating the potential negative health impacts associated with low-quality water (Sima & Elimelech, 2011).

3 Research Questions

This study aimed to empirically evaluate three hypotheses that could explain informal supply and demand dynamics, specifically focusing on whether the emergence of distributive vendors is a consequence of the underperformance of the formal providers.

- Hypothesis 1 (H_1): If there are frequent or prolonged water interruptions, households are more likely to purchase drinking water from distributing vendors on a regular basis and informal activities are likely to be more extensive.
- Hypothesis 2 (H_2): If the quality of tap water is perceived to be poor, households are more likely to supplement their water needs through informal providers and informal activities are likely to be more pronounced.
- Hypothesis 3 (H_3): If the cost of water services provided by formal utilities is perceived to be high, households are more likely to rely on informal services and informal activities are likely to expand.

The study also endeavored to determine whether distributing vendors were committing any form of injustice in the context of the study area. Several studies (Cain, 2018) emphasized the importance of understanding the informal water supply sector in order to determine whether and how it could be adapted to operate alongside the formal system in addressing shortfalls in supply. Thus, this study sought to explore the potential options for formally integrating the informal sector.

4 Formal drinking water services in rural Tunisia: the context of the case study

For decades, Tunisia has made significant investments to improve access to drinking water in rural areas, leading to a notable increase in individual connections to water supply networks. The formal potable water sector in rural Tunisia is characterized by the coexistence of two distinct management systems. The distribution of water in highly populated rural areas is ensured by the national operator called the National Company for the Exploitation and Distribution of Water (SONEDE). Water supply in sparsely populated areas is locally managed by user associations called Agricultural Development Groups (GDAs) (Kammarti et al., 2024).

While the national operator and the user associations both provide formal services, they diverge in their implementation of tariff structures and schedules for generating invoices. The SONEDE water bills include either water services or both water and sanitation services. All users are required to pay a sewer fee in areas where collective sanitation services are provided by the National Sanitation Office (ONAS) and receive a single quarterly bill based on their water consumption. The same tariff is applied nationwide (see Favre & Montginoul, 2018, for more details). Water pricing structures vary greatly among Agricultural Development Groups due to the diverse nature of their systems (Kammarti et al., 2024).

The formal water sector faces several constraints, particularly a physical constraint associated with water scarcity, deteriorating infrastructure, and difficulties in financing projects to rehabilitate and extend the distribution networks that remain entirely handled by the MARHP in rural areas. The inability of formal water utilities and actors to adequately remedy service deficiencies may have led to and could continue to enable the rise of informal alternatives.

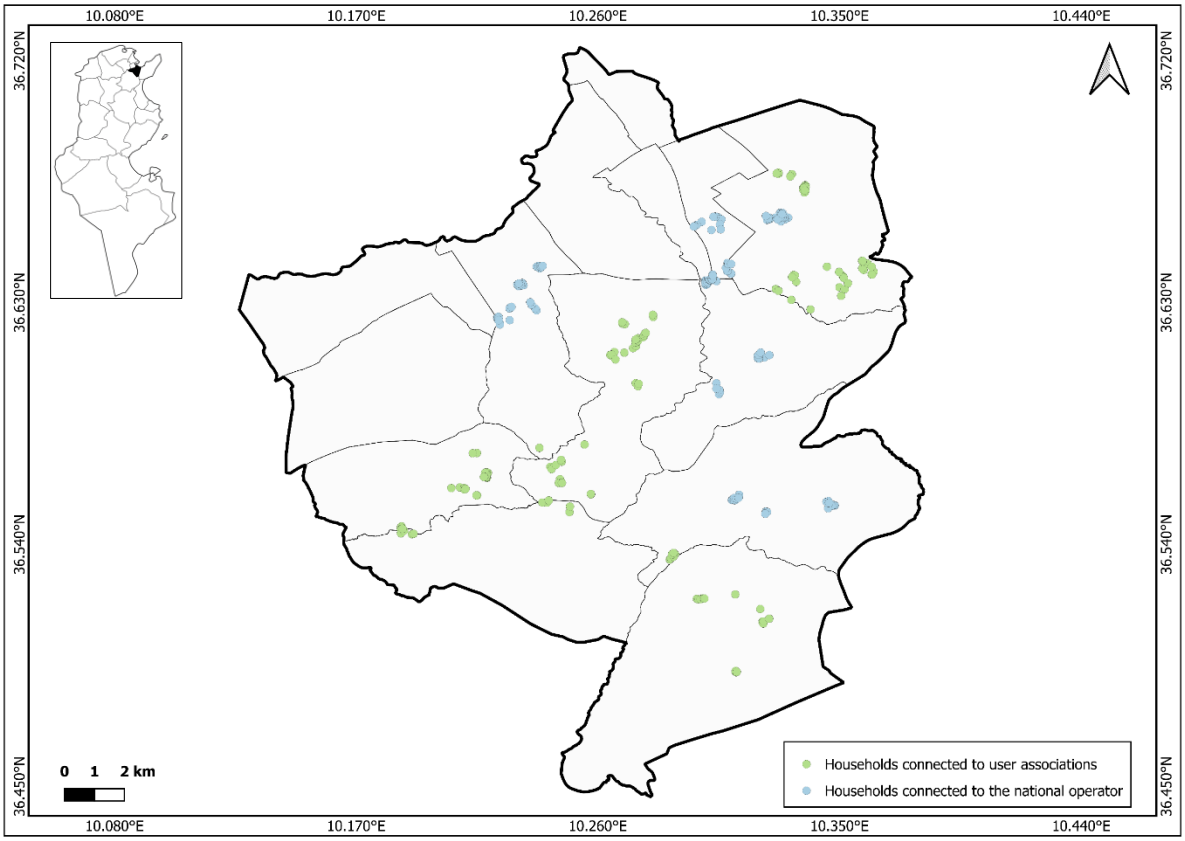
5 Methods

Given the challenges of studying informal water markets, particularly documenting injustices committed by informal water vendors (Wutich et al., 2016), and to enhance our understanding of informal activities, this study employed a household survey methodology to gather client perspectives. The household survey investigated perceptions of the quality and reliability of formal services. It also gathered data on whether respondents had experience purchasing water from distributing vendors. Additionally, the survey explored perceptions of water quality from informal vendors and asked about interactions with these vendors. We also conducted two interviews with distributing vendors to gain a deeper understanding of their insights: one originating from the study area region and serving several locations within it (this individual is referred to as "Locally based vendor" in this paper); the other was not originally from the study area but worked, among other locations, within it (referred to as "non-local vendor" in this paper). The semi-structured interview questions covered 1) the dynamics of informal activities within the study area, including interactions between vendors and the methods used to set prices; 2) the activities of the respondent and their interactions with customers; and 3) their perspectives on the future of the sector, along with potential suggestions for its formalization.

The study was conducted in the Commune of Mornag, Governorate of Ben Arous, Tunisia. The decision to focus exclusively on one commune was made to address a specific concern raised in previous research. Studies examining informal water provision on a broad scale have highlighted challenges in understanding: 1) the diverse ways in which these systems operate, deliver services, and contribute to addressing drinking water scarcity, and 2) how residents perceive the sector (Mapunda et al., 2018). A study in peri-urban Dar es Salaam, Tanzania, demonstrated that analyzing informal water supply systems on a small scale provides a more comprehensive understanding of their functioning (Mapunda et al., 2018). The study area was chosen because of its rural nature and the coexistence of the two formal distribution systems (43% of households are connected to user associations, while 57% are connected to the SONEDE). Since the smallest official geographical division may be characterized by the presence of two formal providers (e.g., N agglomerations connected to the national operator and M agglomerations, each served by one GDA), we used the term 'cluster' to refer to an agglomeration served by a single formal provider. Clusters were randomly selected in the commune without a priori knowledge of whether each cluster received water services from informal vendors. The informal service in a cluster was confirmed when all surveyed respondents living in that cluster reported witnessing distributing vendors' activities and/or when at least one distributing vendor confirmed their activities within that cluster. The initial plan was to survey 30 randomly selected households in each cluster, except for some clusters 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. The survey, conducted from July to August 2022, was only administered to respondents who self-identified as having sufficient knowledge of the current water situation within their households. A total of 322 households were surveyed, with 161 households connected to the SONEDE network and 161 households connected to a network managed by one GDA (figure 1). Informed consent was obtained from all participants prior to data collection.

A comparative analysis was conducted between the group of surveyed households living in clusters receiving informal services (served clusters) and the group of households living in clusters not receiving such services (unserved clusters) in order to examine the determinants of distributing vendors' service provision.

Figure 1: Geographical distribution of surveyed households with a country map highlighting the governorate



To examine the effects of formal water service characteristics on households' use of informal water services, a multiple linear regression model was developed. This model includes the following dependent variables: household water supply situation, perception of piped water quality, and perception of formal water service charges (Table 1). 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. Collecting formally provided water expenditure data proved challenging for several reasons: 1) most respondents reported approximate amounts based on memory, and 2) during the summer, when the survey was conducted, particularly in areas with frequent interruptions, these amounts did not accurately reflect actual consumption or expenditure. Consequently, we used perceptions of formal water service charges as an alternative variable. We assumed that the type of formal water service provider, whether the national utility or local management entity, may influence households' decisions, and to control for potential effects of provider characteristics, a dummy variable representing formal supplier type was integrated into the model.

Nauges and Whittington (2010) explained that models for estimating water demand and analyzing source choice take into account a variety of factors that shape household decisions. These include characteristics of the water source, such as price, quality, and reliability, as well as household-specific attributes like income, size, and education. The authors also noted that collecting accurate income data can be challenging and that previous studies have used several variables as proxies for income or wealth (e.g., household expenditures). Given the possibility of using proxies for income and because of the length constraints of the survey questionnaire, which did not allow for the inclusion of detailed income questions, this study examined household income using a self-reported measure of the minimum

monthly income required to meet basic needs. Ultimately, we decided not to include this variable to prevent collinearity issues, as well as household size, and instead focused solely on variables that address the three hypotheses under investigation. The statistical analyses were conducted using STATA15 software.

Table 1: Variable definitions and classifications

Variable	Description
Dependent variable	
Frequency of purchasing water from distributing vendors (summer 2022)	0 = No use 1 = Once a month 2 = Twice to three times per month 3 = Once a week 4 = Twice to three times a week 5 = Every day
Independent variables	
Household water supply situation	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
Perception of the piped water quality	=1 Good or rather good; = 0 Otherwise
Reporting high water service charges	= 1 Yes; =0 No
Service provided by	1 = GDA; 0 = SONEDE

6 Results

6.1 Formally provided water: Descriptive statistics

41% of respondents reported having a continuous water supply or more than 12 hours of continuous supply per day over the past 1 to 2 months during the summer of 2022 (the period preceding the survey). Meanwhile, 31% reported receiving less than 12 hours of continuous supply per day, 11% reported a supply lasting a few hours to a full day every 2 to 3 days, and 17% reported a supply lasting a few hours to a full day every period greater than 3 to 4 days.

Additionally, 65% of respondents perceived the quality of the formally provided water as poor, and 33% of respondents reported that the charges related to formally provided water were high.

6.2 The informal activity: Dynamics of distributing vendors in the commune

The surveyed vendors confirmed that there was a total of 8 distributing vendors operating in the commune, with 1 vendor residing within the commune and the remaining 7 vendors coming from outside the area. One vendor reported limited communication and coordination among vendors. Each vendor operated independently, setting prices informally and individually. Although prices varied slightly, there seemed to be a general trend of pricing around 1 TND (0.31 USD) per 10 liters. The amounts were converted from Tunisian dinars to US dollars using the December 2022 exchange rate of 1 TND = 0.31 USD. Any additional charges above this common rate were possibly due to the additional fuel expenses incurred to transport water over longer distances to certain clusters further from the source(s). The locally based vendor mentioned that, at the time of the survey, two vendors (himself and another) collected water from springs located in the governorate of Zaghouan, while the remaining six collected water from springs in the governorate of Nabeul, specifically in El Haouaria. The two governorates share borders with the governorate where the study area is located. He added that, even though it is not the case for vendors operating in the commune, there is the option of selling formally provided water (e.g., tap water supplied by the national operator in one region, which customers perceive as being of good quality).

One vendor reported that there was no exclusivity by geographic area for the different vendors. Multiple vendors can operate in the same areas. Consumers have autonomy in selecting vendors they prefer. The locally based vendor mentioned that during times of high demand, clients may request services from any available vendor to fulfill their needs. However, some consumers demonstrated loyalty by waiting for a specific vendor. He cited an example of an area where residents solely accepted his services and declined those of other vendors.

Respondents purchasing water from distributing vendors indicated that the scheduled delivery days were well known, particularly for those living in a cluster served only once a week. In accordance with this finding, the locally based vendor reported that he follows a predetermined delivery schedule. However, he noted that he sometimes makes adjustments to this schedule in order to meet consumer demand. He added that adhering to his established delivery schedule fosters trust in the reliability and consistency of his service.

The locally based vendor stated that the majority of his clients are loyal and regular, and they only seek services from other vendors occasionally during periods of high demand when he is unable to promptly fulfill their requirements. He also mentioned that he goes beyond his capacity to meet the needs of all his clients, such as working at night, and feels a sense of responsibility toward them.

The surveyed vendors expressed high concern about water quality. One vendor reported that he regularly uses a tool to measure the total dissolved solids to ensure that the quality of water is satisfactory. He added that the collected water is immediately sold and never stored or kept too long in the container, so the risk of contamination is low. He also noted that the quality of the water is good

and the stainless-steel container is usually cleaned. He finally added that maintaining quality is important to avoid losing existing customers and potentially gaining new ones.

The locally based vendor expressed that there are two main reasons for preventing him from expanding the geographic scope of his activity: 1) feeling overwhelmed by his existing workload and 2) the distances involved in reaching a given area from the source(s).

6.3 Understanding the motivations behind vendor activity and customer purchases

The results showed that served clusters experienced longer interruptions during the summer of 2022 than unserved clusters. The t-test revealed a significant difference between the two groups. Additionally, tap water quality perceptions among households were poorer in the served clusters than in the unserved clusters. The t-test also indicated a significant difference between the two groups (Table 2). Prolonged interruptions, as reported by households (Hypothesis 1), and tap water perceived as poor (Hypothesis 2) may help explain the presence of informal services.

Table 2: Variables influencing distributing vendors' activities

		Served clusters $N_1 = 244$	Unserved clusters $N_2 = 78$	Results
Household water supply situation*	Mean	3.31	1.63	t = -7.0670 p<0.001
	Observations**	232	75	
Perception of the piped water quality*	Mean	0.27	0.60	t = 5.4577 p<0.001
	Observations**	237	77	

* For description, see Table 1

** Differences due to non-responses and eliminated imprecise responses

Interviews with respondents and observations shed light on two additional potential determinants of the presence or absence of distributing vendors. First, the absence of household demand may be explained by the existence of alternative local water sources, such as natural springs. These alternative sources could satisfy household water needs and therefore explain the absence of informal services. Second, an uninterrupted water supply within a cluster and low household density in a given area or geographical isolation do not necessarily indicate the absence of informal services.

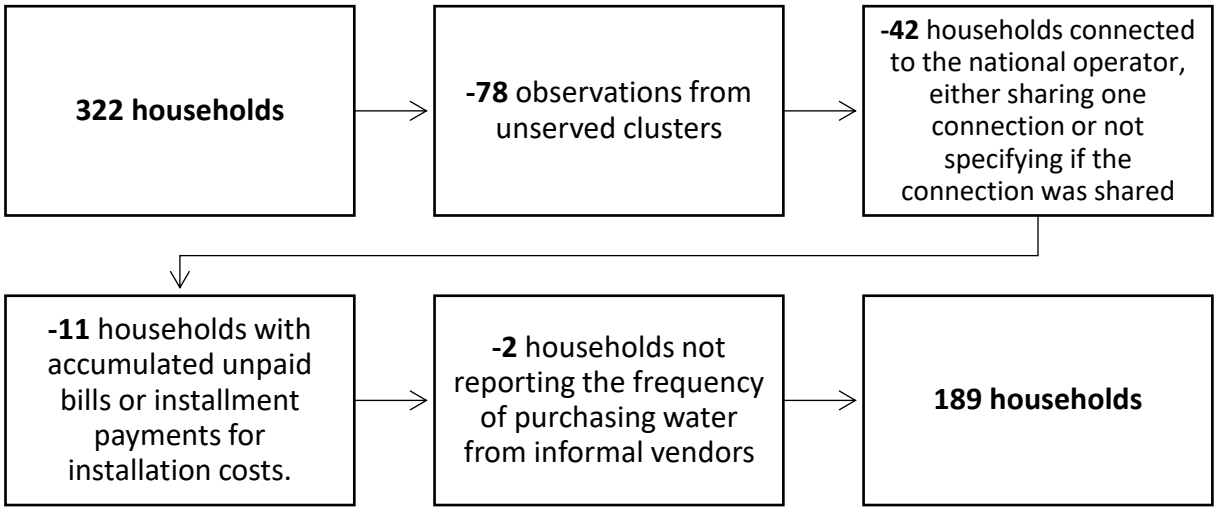
To explain the determinants of households' use of informal services within served clusters, the 78 observations from clusters determined to be entirely unserved by distributing vendors were eliminated from the analysis (figure 2). The use of informal services is outside households' control in areas not supplied by informal providers, as households living in these clusters do not have access to this service regardless of their preference. Households in unserved areas could not actually choose to use informal services, even if they wanted to. The non-use is not a matter of choice or preference in that situation.

Forty-two households served by the national utility that either shared one connection or did not provide information on whether they used a shared connection were excluded from the analysis (figure 2) for the following reasons: under the water pricing structure applied by the national utility, the tariff depends on the water consumption level, and the consumption is charged at the rate of the top band. For households sharing a single connection, water bills are based on the aggregate consumption of all households connected to that meter and do not reflect each household's individual consumption. This total consumption is likely to result in the total billed amount being placed at a higher pricing tier. When

usage is billed collectively rather than individually, households may not accurately perceive how it affects costs.

Eleven households served by the national utility were also eliminated because they had either accumulated unpaid bills or were paying for installation costs in installments, which are included in their quarterly bills (figure 2). This could also impact their perceptions regarding water fees. The elimination steps concluded with 2 households being excluded for not reporting the frequency of purchasing water from informal vendors (figure 2). Regression modeling was conducted using the remaining 189 observations. Due to non-responses and eliminated imprecise responses for one or more variables, the number of observations decreased to 183, as shown in Table 3.

Figure 2: Step-by-Step Elimination Process Illustration



Before running the regression, a multicollinearity test was conducted to check for pairs of variables with correlation coefficients greater than 0.9. As no such pairs were found, no variables were removed.

The results of the regression model demonstrate that the coefficient of the variable PERCEPTION OF THE PIPED WATER QUALITY is statistically significant at the 5% level (Table 3), indicating that perceptions of water quality influence households' use of informal water services. This finding aligns with previous studies. Perceptions of the quality of the water source under study, as well as the quality of alternative sources, are commonly included in models analyzing water source choice and have been found to significantly influence household decisions (Nauges & Whittington, 2010). The results revealed that households connected to local operators were more likely to buy water from distributing vendors. The sample of surveyed households included two groups: those connected to GDAs and those connected to the national operator SONEDE (Table 4). This heterogeneity (e.g., 70% of households connected to GDAs and 31% of households connected to the SONEDE respectively reporting purchasing water from distributing vendors at least once a week during the summer of 2022) could explain why the statistical analysis identified the variable related to the formal service provider as a statistically significant predictor of households' use of informal water services (Table 3). This finding cannot be assumed to reflect wider rural trends because the study examined only one specific local setting.

The coefficient of HOUSEHOLD WATER SUPPLY SITUATION, representing whether a household faced water service interruptions and offering insight into the frequency of such interruptions, was not statistically significant (Table 3). This finding suggests that interruptions do not influence households' use of informal water services. Another justification showing that interruptions are not one of the reasons for the emergence of this informal activity is that 65% of the respondents, who experienced no interruptions during winter, purchased water with the same frequency throughout the year. Within this

group, 39% also purchased the same volume. The surveyed vendors confirmed that their activities occur year-round, although the frequency may decrease in winter when demand is lower than in summer.

Table 3: Linear regression: variables influencing households' use of informal water services

Variables	
Household water supply situation	-0.0670
	(-1.11)
Perception of the piped water quality	**-0.596****
	(-2.23)
Reporting high water service charges	-0.232
	(-0.95)
Service provided by the SONEDE (0) or a GDA (1)	**1.564*****
	(6.45)
(constant)	**1.373*****
	(4.91)
R^2	0.2364
Observations	183
* p<0.1, ** p<0.05, *** p<0.01 Numbers in parentheses are corresponding t-statistics	

Affordability is generally assessed using indices that calculate water and sanitation expenditures as a percentage of the available household budgets (Favre & Montginoul, 2018). A study conducted in the governorate of Kairouan (Central Tunisia) by Favre and Montginoul (2017) on a sample of households individually connected to the piped networks of the national operator revealed a global affordability index of 1.3%. Since affordability indices must account for different income levels to avoid average values obscuring broad disparities related to poverty, the study also showed that the poorest 20% of households spend 2.1% of their income on water consumption compared to 0.8% for the richest 20%. To the best of our knowledge, no prior study has examined the affordability of formal water services provided by local actors in Tunisia. However, our research found that 75% of households connected to a GDA in served clusters reported that the water service charges were not high (Table 4). The affordability of formal services could explain the insignificant impact of formal service charges on the use of informal services.

The poor quality of formally provided water led customers to buy water from informal vendors (Hypothesis 2). This finding aligns with a vendor's statement that this activity would likely not occur if the quality of the formally provided water was better.

Table 4: Descriptive statistics and t-tests' results

Service provided by	the SONEDE	a GDA	t-tests' results
The percentage of households reporting purchasing water from distributing vendors at least once a week during the summer of 2022	31%	70%	t =-5.7948; p = 0.0000
Observations	**78**	**111**	**189**
The percentage of households reporting **no water service interruptions** during the summer of 2020	36%	19%	t =-5.2469; p = 0.0000
Responses*	78	108	186
The percentage of households reporting **good** tap water quality	31%	20%	t = 1.6607; p = 0.0985
Responses*	78	109	187
The percentage of households reporting water service charges as **not high**	60%	75%	t = 2.0933; p = 0.0377
Responses*	78	110	188
* Differences due to non-responses and eliminated imprecise responses			

6.4 Water purchased from Distributing Vendors: Uses, perceptions, and price comparison: Informal vs. Formal

In the served clusters, 54% of respondents reported purchasing water from distributing vendors. The key uses identified were for drinking and food preparation. 44% of the respondents reported using purchased water as a substitute for formally provided water solely for drinking. 17% used it as a substitute for formally provided water for both drinking and food preparation. 20% used it as a complement to formally provided water strictly for drinking, and 11% used it as a complement for both drinking and food preparation.

A limited number of respondents expressed uncertainty about the origin or lack of knowledge regarding the source as a reason for not purchasing water from distributing vendors. This finding contradicts the assertion made by the locally based vendor, who claimed that customers are well informed about the origin of water. It is plausible that the individuals who raised this concern are not customers of the locally based vendor, who ensures that his clients, primarily neighbors and acquaintances, are fully aware of its origin. This observation highlighted the significant role that trust plays in shaping relationships within this market. This result aligns with the findings of Kariuki and Schwartz (2005) in that most vendors operate on a small-scale level and in peri-urban, rural, and remote areas where they reside. Given that people in these communities typically know one another, customer service and relationships are of high importance, and many business transactions are conducted based on mutual trust.

Within the served clusters, none of the respondents reported experiencing rejection from vendors or having their requests ignored. 97% of the respondents who purchased water from distributing vendors reported being satisfied with its quality. Questions regarding water quality remain unresolved. Without conducting particular laboratory tests, we are unable to conclude whether the water poses any risks to human health or is inferior in quality compared with piped water. However, the vendors surveyed

appear to place great importance on both verifying water quality, as evidenced by their regular measurement of total dissolved solids (TDS) levels at the source, and on properly maintaining and cleaning the equipment used to transport the water.

None of the respondents who purchased water from distributing vendors claimed that the water prices were high. The unitary prices per cubic meter at the time of the survey ranged from 0.2 TND (0.06 USD) to 1.620 TND (0.52 USD) for the national utility and from 0.7 TND (0.22 USD) to 2.2 TND (0.7 USD) for Agricultural Development Groups operating in areas served by informal providers. The average price of a 10-liter Jerrican sold by informal providers was 1.035 TND (0.33 USD), approximately 64 to 518 times, and 47 to 148 times the unitary price per 10 liters charged respectively by the national utility and local actors at the time of the survey. This mean is the result of a slight heterogeneity in prices between served clusters and within the same clusters, as a few households reported purchasing water at a price slightly lower than what is commonly charged in the cluster where they live. The few reported prices lower than common prices within a cluster can be attributed to client-vendor interactions that shape informal water markets (Wutich et al., 2016).

7 Discussion

Using a mixed-method approach, employing both qualitative and quantitative research methods, allowed us to better explain the phenomenon in question, even with the challenges of surveying informal vendors.

The study found that two key factors empirically determined the incentives for distributing vendors to serve a given area/cluster: frequent/long interruptions and the poor quality of formally provided water. However, this study demonstrated that only the poor quality of formally provided water led customers to buy water from informal vendors. The research showed that customers connected to locally managed piped networks were more likely to buy water from vendors than those connected to the national operator's networks. This finding does not indicate that the national operator provides higher quality services. The results are specific to the area under examination and should not be generalized to other locations without further research.

According to customers, it seemed that distributing vendors were not committing distributive injustice if this form of injustice is defined as charging high prices and/or providing water of poor quality. Even though the prices were significantly higher than those of formal water services, there was almost no expression of dissatisfaction with pricing or quality. According to customers, informal activities appeared regular and informal providers did not demonstrate any mistreatment. No form of procedural or interactional injustice was then detected. According to Wutich et al. (2016), these types of injustices, which are less commonly recognized but still significant forms of injustice, remain poorly understood and have not been sufficiently studied. As a result, this finding cannot be generalized to every context, and further research is necessary to enhance the comprehension of these types of injustices in various rural and peri-urban settings within Tunisia.

When considering potential injustice in how vendors operate, a question arises: could deciding not to serve a given area be viewed as a way to optimize costs, or should it be seen as a form of injustice? From the vendors' perspective as entrepreneurs, the answer is straightforward: where there is demand and potential for profitability in a given area/cluster, in the limit of their capacities, they will choose to serve that area. Unlike formal providers, which have the ability to operate on a large scale over the long term, one vendor has limited capability for expanding their activities in the short term.

Although the sample size was small, the two surveyed vendors accounted for 25% of all vendors active in the study area. Additionally, this sample included one locally based vendor and one non-local vendor. While there is no universal agreement on the appropriate sample size for similar studies, we determined that these interviews allowed us to develop a robust understanding of the activity in question within the limited geographic scope of the study area.

Although the study did not compare locally based vendors and non-local vendors or assess customer attitudes toward each, one aspect that was observed was the locally based vendor's strong sense of solidarity. This vendor expressed having freely provided water to those in vulnerable situations. The key finding is that trust plays a crucial role in this informal market and determines whether customers will purchase water from distributing vendors.

We found that vendors view themselves as entrepreneurs but also as helpers assisting formal utilities in addressing the water crisis by providing an alternative to formally provided water of poor quality at a lower price than bottled water for those unable to afford bottled water.

8 Recommendations

During periods of prolonged service interruption or in areas where formally provided water is of poor quality, incorporating elements of the informal water sector into formal systems could serve as short- to medium-term crisis response measures and help affected communities access the water needed for drinking, cooking, and basic hygiene. Rather than uncontrolled sources, regional authorities and formal providers should establish controlled collection points that supply treated water. These points could upgrade currently unimproved sources used by vendors. This approach aims to avoid distributing vendors obtaining water from undisclosed and untested sources, such as springs, wells used for irrigation on farmland, and taps of piped households served by one of the formal operators in areas without service interruptions. A few questions arise regarding this recommendation: 1) How will distribution operations be handled safely at source points? 2) To what extent must authorities be involved in this process? 3) How can it be ensured that vendors do not use uncontrolled sources for distribution? 4) What steps can be taken to ensure that storage and transport conditions do not pose health risks?

Informal-formal partnerships could help to meet basic water needs regularly throughout the year for unserved households not connected to a formal network through individual connections. However, several important considerations must be addressed to ensure long-term sustainability. The questions of governance and accountability require deeper discussion before implementation. Expanding research would strengthen the analysis of challenges and opportunities to develop sustainable informal-formal partnerships over time.

Additionally, gathering information about the use of this informal service through a local survey can provide useful insights into willingness to pay for improved services (Whittington et al., 1989). Expenses currently paid for informal services by rural households could thus be taken into account when considering adjustments to tariff rates that better enable coverage of the costs associated with formal water access.

9 Conclusion

The informal water market appeared to be shaped by multiple factors, including the existing formal provider, the quality of the formally provided water, distributing vendors' attitudes toward their clients, levels of trust and relationships between customers and vendors, and customers' perceptions regarding the informal service (water quality and reliability).

Through our analysis in a context where all households have an individual connection to a formal network, we determined that one contributing factor to the rise of informal vendors is the underperformance of the formal providers, manifested by frequent or prolonged water interruptions and poor water quality.

We do not intend to generalize the findings of this study because the characteristics of the informal sector are closely tied to the local context. In other settings, key parameters, such as the origin of

informally provided water, the number of distributing vendors, and relationships between vendors and clients, may differ in ways that could greatly affect informal supply and demand dynamics.

The study concluded with policy recommendations focusing on the need to recognize informal activity and regulate associated markets, as proposed by Sima and Elimelech (2011), Venkatachalam (2015), and Liddle et al. (2016), among several others. This could help ensure that these informal activities, characterized by a quick response to changing needs, non-reliance on permanent infrastructure, and low or no capital costs compared to piped networks, play a fair supplementary role in meeting rural communities' needs until infrastructure is improved or in the case of conjunctural problems like scarcity.

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