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Valuing the water supply: ecosystem-based potable water supply management for the Legedadie-Dire catchments, Central Ethiopia

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Abstract

Background: There is a substantial interest in the values that consumers place on drinking water quality and supply. Financial resources are crucial to improving the urban potable water supply in developing countries that are characterized by low-cost recovery rates and a high and rapidly growing demand for more reliable services. This study examined households' willingness to pay (WTP) for the improvement of water services by identifying their water choice decisions and the mode of water supply that they prefer the water supply authority to use among several alternative water supply options. Stated-preference data were collected from 322 randomly selected households in Addis Ababa, who were presented with three sets of choices (three alternative bundle choices, including the reference scenario). The data were analyzed using the mixed logit WTP space model. Three approaches to modeling the distribution of WTP (fixed, uncorrelated, and correlated) using mixed logit WTP space models were compared.

Results: Three-quarters of the households agreed to contribute money toward ecosystem-based water supply management (EBWSM) intervention programs on a monthly basis. The average contribution that the respondents were willing to pay was 150.5 Ethiopian Birr (ETB) as a one-off lump sum to kick off the EBWSM activities. Most of the respondents chose a bundle of water supply options that provides risk-free and high-quality water with no months of shortages than moderate water quality that is safe to drink and palatable with 1 month shortages annually. This implies that households would need to be supplied with risk-free, high-quality water without interruption at an appropriate flow pressure. The model with correlations fitted the data well with the highest simulated log-likelihoods at convergence and gave the best estimate of the households' WTP for water improvement. Nearly 46% of the sampled households were willing to pay more than 33 ETB per month, and 49% of the households were willing to pay between 21 ETB and 33 ETB per month for the monthly water bill. Overall, approximately 95% of the sampled households were willing to pay more than 21 ETB.

Conclusion: Customers are willing to pay to avoid most types of water supply restrictions. Moreover, WTP is sensitive to the scope of service improvement, income, affixed price, and elicitation method. In summary, mixed logit WTP-space models can help accurately predict household-level WTP, which can be used to select improvements in drinking water access and services in the Legedadie-Dire catchments.

Keywords: Ecosystem service, Water supply, Mixed logit, WTP-space model, Catchment management, Legedadie reservoir

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Introduction

Urban drinking water is publicly supplied under regulation. Globally, nine of every ten people do not have their wastewater treated to any degree, five of ten have inadequate sanitation, and two of ten lack access to a safe water supply (World Bank 1996). In most parts of Ethiopia, the low public investment and insufficient tariffs in urban water supply systems have resulted in low levels of service, rationing, and unscheduled disruptions (World Bank 1996). Running the existing water supply system in Ethiopia is constrained by an enormous financial gap, which creates a burden for the government (Brixi 2009; Butterworth et al. 2013; Ludi et al. 2013). For example, the government covers nearly 44% of the financial costs of the entire water supply program in the country, and the remaining 56% is covered by external support agencies (Tarfasa 2013). Nevertheless, financing the water supply system is imperative to diversify livelihood options for the urban poor in addition to ensuring their access to water because the lack of water supply, hygiene, and sanitation takes an enormous toll on health and well-being and has a large financial cost, including a sizable loss of economic activity (Connor 2015). Limited access to water is a particularly large burden to women's economic empowerment because women in many countries continue to carry the full burden of water inequality. Studies show that women bear the primary responsibility for water collection. Time lost due to walking and waiting for water has a ripple effect on their lives, their communities, and the entire economy. This time cannot be spent carrying out income-generating activities to diversify their livelihoods, which could contribute to poverty alleviation and social and economic development (WWAP 2015; Connor 2015). Thus, ensuring an improved water supply system is key to promoting their livelihoods and broadening the diversification options.

Generally, two approaches can be used to measure the economic value of the quality and availability of nonmarket commodities: revealed preference and stated preference approaches (Vuletić et al. 2009; Freeman III et al. 2014). In the revealed preference method, the values of nonmarket environmental goods and services are inferred from other market transactions; these methods include aversion cost, travel cost, and hedonic pricing (Pearce 2002; Adamowicz et al. 1994). The stated preference method is based on hypothetical questions that allow individuals to report their willingness to pay (WTP) for the intended service or value (Adamowicz et al. 1994). This method includes common variants such as the contingent valuation and discrete choice experiment (DCE) approaches (Mogas et al. 2006). Both contingent valuation and DCE approaches present respondents with a survey of questions to assess whether they are willing to pay for modifications to features of the product in question. The survey gives respondents a list of alternative scenarios characterized by several attributes (Adamowicz et al. 1998).

Although contingent valuation is the most frequently employed valuation tool in environmental economics (Bateman et al. 2003), it is often criticized as being inadequate to value a single attribute of multiattribute nonmarket goods and services (Louviere et al. 2000; Bateman et al. 2003). In contrast, the DCE approach enables the investigation of an attribute of a product and model in an individual or a household's decision-making process in a hypothetical situation (Louviere et al. 2000), which makes it an appropriate alternative tool. DCE is a survey-based methodology for modeling preferences for goods that can be described based on their attributes and levels. Several alternative descriptions of a good, which are differentiated by their attributes and levels, are presented to respondents, who rank or rate their preferred choices. By using price an attribute of a good, WTP can be indirectly recovered from the respondents' rankings, ratings, or choices. Like contingent valuation, DCE can estimate all forms of value, including nonuse values. Its conceptual microeconomic framework lies in the characteristics theory of value of Lancaster (1966), which assumes that consumers' utilities for goods can be decomposed into utilities for their characteristics. DCE has been applied in environmental science more recently than in market-based and transport-related research, where it has been widely used. As recommended by Carson and Louviere (2010), the term "discrete choice experiment" is used throughout this article to avoid confusion because the expression "choice experiment" has different connotations in other disciplines, such as physics and biology.

Payment for ecosystem services

Payment for ecosystem services (PES) schemes are designed so that buyers purchase—more or less explicitly—services from providers (Rowcroft et al. 2011). PES schemes may be a compliment or a substitute for regulations under which land and water operators must observe certain levels of ecosystem provisions (DEFRA 2013). The payments represent an explicit economic encouragement to land managers to deliver ecosystem services (ESs) via market-like incentives (Thomson et al. 2014) because there are direct influences on the provision of many ESs, of which land managers are often not aware (Bonn et al. 2009). For example, water quality has deteriorated due to the application of modern agricultural inputs, such as pesticides and fertilizers. Moreover, land managers are often unfamiliar with the impacts of their actions on downstream users and third parties, such as downstream water users (Molle 2004).

These so-called externalities can be positive or negative. Market prices have typically overlooked and ignored such environmental externalities (Chander and Tulkens 2006). Even if the impacts of upstream activities on ESs are clearly understood by land operators, including these services into their management activities is not in their economic interest because they provide them no additional benefit (Chander and Tulkens 2006). A PES scheme for a watershed includes various stakeholders, such as landowners (upstream and downstream), farmers (which may be landowners but also potential polluters), local and distant domestic consumers, enterprises that require clean water (e.g., distilleries, food, water processors), and fishermen as well as residents and state governments and agencies.

One way to address land managers' externalities is via mechanisms that integrate the externalities into transactions systems of PES schemes (Van Bueren and Bennett, 2004). Land managers are rewarded (usually through cash payments) by resource users for providing ESs under PES schemes, thereby internalizing the externalities (Engel et al. 2008). Service beneficiaries, such as urban dwellers, who obtain their potable water from an upstream catchment should have to reward service providers, such as upstream farmers, as land managers, which is the basic principle behind ecosystem service providers. These rewards are manifested by incentivizing farmers for their efforts in supplying these services in a sustainable fashion to the benefit of buyers, sellers, and nature itself. This approach is expected to have multiple advantages because it values many nature services that are commonly taken for granted while simultaneously raising awareness of service existence and human impacts and highlighting the social interdependence of providers and buyers.

The context of drinking water supply in developing countries

It is commonly accepted that sustaining human life and ensuring good health and human dignity are directly associated with the provision of potable water, sanitation, and hygiene (Akinyemi et al. 2018). This encourages the formation of a more reasonable, productive, and healthier community structure. Water quality continues to be the concern of many developing countries despite the steady improvement in drinking water supply throughout the world (Watkins 2006).

Clean and safe drinking water is one of the most important necessities of life. Currently, water scarcity affects more than 40% of people around the world, and by 2030, the global demand for water is expected to increase by 50% (Habitat, U.N 2016). According to Bryce et al. (2005), approximately 844 million people globally lack access to a supply of potable water, and approximately 2.5 billion

people have no access to adequate sanitation. Today, many developing countries face serious problems related to water. Evidence abounds that public water supplies in rural and semi-urban centers in developing countries, such as in Africa, are generally inadequate and unreliable compared with the rate of population growth (Jideonwo 2014; Coster and Otufale 2014; Ben and Ogunyemi Omotayo 2015).

Khan et al. (2006) estimated that in 2000, Africa had 28% of the world's population without access to clean water. It was also estimated that 319 million people in sub-Saharan Africa (equivalent to 51% of the population) lack access to a supply of safe water and that 41% lacks adequate sanitation. The others obtain water from sources such as wells, boreholes, and streams, which may not be clean. Scarcity of drinking water causes higher rates of sickness and death and leads to higher health costs, low work productivity, lower school enrollment, and ultimately poverty (Ahmad and Sattar 2010).

Challenges in the water sector are also challenges for the food production sector and thus are obstacles to meeting other societal necessities and goals. For example, approximately 70% of water use is accounted for by the agricultural sector (Alcamo et al. 2017), which supports the livelihoods of large numbers of households worldwide. Therefore, in their attempts to design and apply effective strategies, poverty assessment researchers have identified water as the critical element and have consistently proposed improvements in water supply services as a working approach for poverty reduction. The challenge is even more severe in Africa, where water stress is already evident in approximately 14 countries, and an additional 11 countries are expected to experience water stress by 2025. This will cause nearly half of Africa's population to face water stress or scarcity by 2025 (Hoekstra et al. 2012). Reducing the population that lacks access to adequate water and basic sanitation by half, which is enshrined in the millennium development goals (MDGs), would help to ensure the availability and sustainable management of water and sanitation for all.

Ethiopia is one of the sub-Saharan African countries that has a discrepancy between the demand for and supply of improved drinking water (Soto Montes de Oca and Bateman 2006). Approximately 43% of the population does not have access to an improved water source, and 28% practice open defecation. In addition, the prevailing very low and insufficient income and subsidies given to the expansion and maintenance of water facilities and infrastructure that are necessary to ensure an improved water supply (Gadgil 1998) have had a significant impact on health. Approximately 60 to 80% of communicable diseases are attributed to the limited access to safe water and inadequate sanitation and hygiene services (Tessema 2017). An estimated 22% of children under five die because of diarrhea (the third leading

cause of under-five mortality), which is attributed to poor water, sanitation, and hygiene. Diarrhea prevalence is highest among children residing in households that drink from exposed wells (18%) and those residing in rural areas (14%). Nearly 50% of the consequences of undernutrition are caused by environmental factors that include poor hygiene and a lack of access to water supply and sanitation (Tessema 2017). Moreover, the majority of health facilities in Ethiopia lack access to clean water, and only approximately 32% have access to safe water (Welle et al. 2012).

Generally, evidence suggests that people's health and living conditions can be improved by preventing the spread of fatal diseases through improved water access (Akinyemi et al. 2018). Therefore, working toward improved water access substantially helps to address the challenges of poverty, hunger, health, and inequality in an integrated approach (WaterAid 2017). Such an approach incorporates the productivity and survival of human life and agro-ecosystems into its key services for people (Dessalegn and Merrey 2015). In this regard, the limited financing of this sector remains a bottleneck to addressing the challenges of improved water supply given its capital-intensive nature. One factor that has contributed to the water sector's financial problems is the increase in the volume of unaccounted water; treated water is not accounted for since its precise destination is not known. It is estimated that approximately 36.5% of the average daily production of water in Addis Ababa is unaccounted for because of leaks, metering inaccuracies, bursts of old pipes, theft, or illegal connections. Moreover, tariff levels remain below the cost recovery levels. The low tariffs and inadequate government investments make it difficult to supply improved water. The prevailing large water supply deficit and poor water quality signals the presence of high demand for improved water supply service; hence, it is likely that most residents would be willing to pay more for the service once it has been improved.

Water supply issues in Addis Ababa

The city of Addis Ababa is located downstream of the Legedadie-Dire catchments, which are part of the Akaki River Basin (Ebba 2006). The city has been divided into ten subcities for administrative purposes by the city government (Fig. 1) and has been further segmented into eight water distribution branches of authority (Fig. 2) by the Addis Ababa Water and Sewerage Authority (AAWSA). Water users are distributed over these eight water supply branches in the cities. Thus, residents of a particular sub-city can be supplied with water from different distribution branches even though they are within the same administrative sub-city.

Previous studies have shown that land use and land cover change (LULCC) over the past several decades

(Anteneh et al. 2018a), combined with improper utilization and poor natural resource management of the land, rivers, vegetation, and the ecosystem at the catchment level, have led to sedimentation and siltation of the Legedadie and Dire reservoirs (Gebresamuel et al. 2010; Anteneh et al. 2018b). This has accelerated the deterioration of the reservoir water quality and quantity (Kebede and Kebedee 2012). Silt deposits (Andualem and Yonas 2008), algal blooming (Mesfin and Belay 1989; AAWSA 1994), heavy metals such as lead (Tamene 2008), pathogens (Mesfin and Belay 1989), and other pollutants have significantly affected both the quality and quantity of the reservoir water. Crampton and Ragusa (2008) indicated that water contamination in Addis Ababa has low levels of risk but a very high frequency of infection. In a study of how clean drinking water at the water source can be contaminated before human consumption, Crampton and Ragusa (2008) noted that of the 127 water samples collected, 34% were contaminated with fecal bacteria, 33% of water sources were contaminated ($n = 72$), and 37% of the point-of-use water samples contained fecal bacteria ($n = 54$). Although 34% of samples tested positive for some level of contamination, 52% of these scores were at a level that would present low risks to human consumers.

The live storage capacity of the Legedadie reservoir decreased by 2.1 million cubic meters (Mm^3) from 1979 to 1998 with an annual sediment load of 110,000 m^3, and it deceased by 1.62 Mm^3 from 1998 to 2010 with an annual sediment load of 135,000 m^3 (MPR 2011). This situation has had a substantial impact on the quality, quantity, pressure, and distribution of the water supply. Currently, the demand for water in Addis Ababa exceeds the supply, and the demand for potable water is growing nearly three times faster than the water supply. The total potable water demand of the city increased from 206,230 m^3 per day in 1994 to 326,137 m^3 per day in 2002 (AAWSA 2004), 380,000 m^3 per day in 2004 (Sime 1998), and 616,108 m^3 in 2011 (AAWSA 2004), and it is projected to reach 1,105,000 m^3 per day in 2020 and 1,329,585 m^3 in 2025 (Sime 1998; AAWSA 2004). The total annual water production of the city also increased from 55 Mm^3 in 1992 to 64 Mm^3 in 1998, 80 Mm^3 in 2004, 92.2 Mm^3 in 2008, and approximately 109.5 Mm^3 in 2011 (Bereket 2006).

Most studies in Ethiopia have reported water pressure in meters of water column (mH_2O), where 1 pounds per square inch (PSI) is equal to 0.70307 mH_2O. Customers often complain that the water pressure is very low in most parts of the city (Gamtessa 2008). Reports of the water supply pressure in Addis Ababa are varied. The Addis Ababa water supply has been reported to be 45 PSI (TAHAL, SMEC, WWDSE, HyWAS 2005), 34 PSI (Liemberger et al. 2007), and 36 PSI (Mengistu and
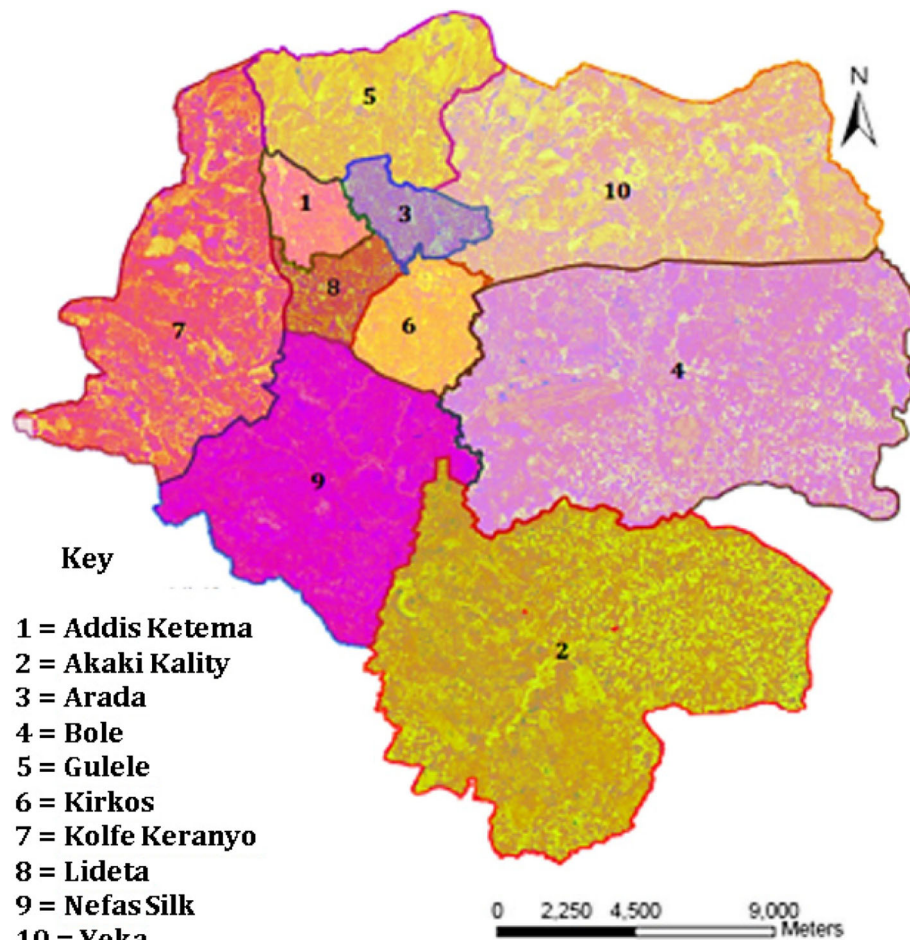
Fig. 1 Map of the ten subcities in Addis Ababa

Savage 2010). According to Twort et al. (1994), the domestic water pressure for residential purposes tends to range from 45 to 80 PSI. A water pressure below 40 PSI is considered to be low, and a pressure below 30 PSI is considered to be too low (Twort et al. 1994). A pressure above 80 PSI is too high (Twort et al. 1994). Low water pressure is more of a nuisance and contributes to water scarcity, although some equipment has minimum requirements, such as washing machines. In contrast, high water pressure significantly increases the risk of damage to pipes, joints, and fixtures and increases water waste (Witzke et al. 2012). For example, urban supply pressures in the UK are 4–5 bar (60–70 PSI), and the minimum pressure is 40 PSI in Idaho, USA (Colby et al. 1989).

The mean daily per capita domestic water demand in liters is estimated to have been 61 l/c/day in 2011, 83 l/c/day in 2015, and 95 l/c/day in 2017 and is projected to be 105 l/c/day in 2019 and 110 l/c/day by the end of 2020, which represents an annual increase of 6.6% (AAWSA 2011). Based on the AAWSA's records, the total billed volume of water in 2010 was approximately 62.35 Mm^3, of which approximately 50.4% was for domestic consumption, 48% was for nondomestic use, and 1.7% was for public tap users. The total annual water demand for Addis Ababa is estimated to reach 252 Mm^3 by 2020, of which an average 68% is the domestic water demand, and 32% is for nondomestic demand.

Generally, the value of drinking water does not depend solely on its quantity, quality, and pressure but also on several other factors, such as location or distance from the source, travel time and time of availability, the taste of the water, and the reliability of access. Improved water supply service management requires decisions based on social equity, economic efficiency, and ecological sustainability. Thus, this study is important for water supply service management and pricing options for users across the subcities with reference to the estimated WTP results. Moreover, attaching a monetary metric to water services is helpful for planners, policy-makers, and decision-makers to make appropriate decisions regarding development and better allocation of urban drinking water supply service.
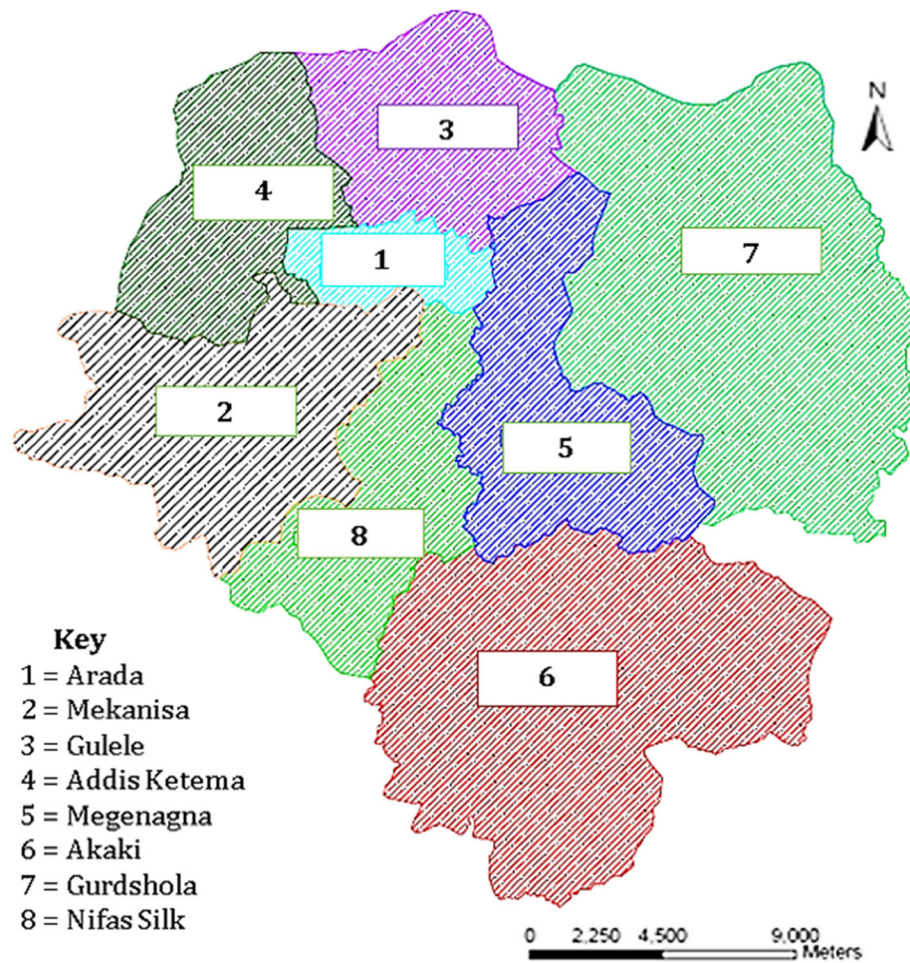
Fig. 2 AAWSA water distribution branch offices in the city, which do not follow the sub-city boundaries

Methodology

Survey design of the discrete choice experiments

We assumed that the current drinking water supply requires improvement to satisfy the needs of the customers. In considering how individuals make choices about the water supply as a good, Lancaster (1966) noted that the supplied water characteristics give rise to consumer satisfaction. Water supply usually exhibits multiple characteristics (e.g., quality, quantity, pressure), and many water supply approaches use individual characteristics. In addition, a combination of various water supply approaches will give rise to features that are not present when each water supply characteristic is examined separately. This approach indicates that to understand consumers' water supply choices, researchers must understand how consumers value the specific characteristics of the water supply separately as well as in combination (Lancaster 1966).

The first step in designing a choice discrete experiment is to identify the ecosystem-based water supply management (EBWSM) choice attributes and define their levels (Table 1). The attributes should have policy

implications and be related to the suggested interventions and expected outcomes. Hence, they should be relevant to the policymaking process. Supply and demand-driven approaches have been considered in determining and developing the choice attributes and levels (Sangkapitux et al. 2009). The supply-driven approach has been used in studies of the city's water supply and impoundment (Elala 2011; Taye et al. 2013; Andualem and Yonas 2008; Bereket 2006; Mengesha 2014), catchment rehabilitation and ES management (AAWSA 2011), and prevailing land change and resources degradation in the catchments (Taye et al. 2013).

Moreover, to help in the process of the DCE design, a pilot survey was conducted on 53 sample households in the Akaki subcity as a demand-driven approach. The main objective of the pilot survey was to understand the resident's perspectives towards the existing water supply system and to incorporate the data into the design of the EBWSM choice attributes and levels. Three EBWSM attributes were identified, and their levels were used in the DCE design (Table 1).

Table 1 Attributes and levels used in the DCEs to improve EBWSM

No	Attributes	Description	Current status/status quo	Attribute levels
1	Water quality	Improvement of the quality of municipal drinking water from the source via upstream EBWSM interventions (reinstate riparian ecological conditions via buffering along rivers and reservoirs, application of conservation agriculture with controlled grazing, grass filter strips, and reforestation activities on degraded lands) in the Dire-Legedadie catchments. This can improve not only the surface water supply (such as water stored in the reservoirs) but also augment the potential of the upstream catchment in recharging groundwater sources (Akaki wellfields).	High risk of contamination	Risk-free and high-quality water Moderate water quality yet palatable and safe to drink
2	Water quantity	Application of upstream catchment EBWSM interventions (afforestation and reinstate riparian ecological conditions via buffering along rivers and reservoirs) that can initiate continuous water flow to reservoirs by reducing sedimentation and improving the storage capacity of the reservoirs in the Dire-Legedadie catchments. This will increase the drinking water supply. Such interventions can improve the surface water supply (such as water stored in the reservoirs) and also augment the potential of the upstream catchment in recharging groundwater sources (Akaki wellfields).	2–3 months of shortages annually (1 week–10 days/month)	No months of shortages 1 month of shortages annually (2–3 days/month)
3	Water pressure	Management of water distribution systems and improvement of flow pressure by installing leak detection and pressure control equipment and other water distribution facilities that can conserve unnecessary drinking water leakage and unaccounted water losses.	Unpredicted and low pressure in most areas	Normal pressure (40 to 55 PSI)
	Compensation payment	Households' WTP for an improved municipal water supply per month in addition to the monthly water bill.	No payment	12.50, 18, 21, 25, 29, and 36 ETB per month

Water supply alternatives are based on various combinations of specific water supply attributes, including the water quality, water quantity, water pressure, and alternative price options. Various water supply studies have included four to six alternative price options (Mulatu 2013; Tanellari et al. 2015; Um et al. 2002; Casey et al. 2006; Genius et al. 2008; Vásquez et al. 2009). Considering the socioeconomic characteristics of the respondents as well as the previous studies, we presented six alternative price options in this study. Each payment choice depends on the chosen alternatives and is to be paid by households with their monthly water bills, including 12.50 ETB month^{-1}, 18 ETB month^{-1}, 21 ETB month^{-1}, 25 ETB month^{-1}, 29 ETB month^{-1}, and 36 ETB month^{-1} (where 1 ETB ≈ 0.0494 United States dollars; USD). To provide flexibility for the households, we use diverse rather than fixed ranges between each price option from 3 to 7 ETB.

Choice 1 includes a bundle of water supply options that provides moderate water quality that is safe to drink and palatable with one month shortage annually (2 -3 days month^{-1}) and normal water pressure (40 to 55 PSI).

Choice 2 contains a bundle of options that provides risk-free and high-quality water with no months of shortages annually and normal pressure (40 to 55 PSI).

Choice 3 (i.e., the reference scenario or status quo option) includes water quality with a high risk of

contamination, two to three months shortages annually (i.e., 1 week to 10 days month^{-1}) with unpredicted (i.e., extremely low or extremely high) pressure as per the 2011 AAWSA business plan.

The WTP elicitation questions were formulated to determine whether the respondents would be willing to pay a certain amount per year with their monthly bills in support of water supply improvement efforts (Table 2). The questions must be administered prior to the DCE survey; hence, if the household were not willing to participate in the EBWSM, he/she would be given the protest follow-up questions instead of the subsequent DCE alternatives. The survey design also included questions to generate information about the sociodemographic characteristics and the existing water demand and supply situation as well as the overall purchasing behavior and attitudes toward the drinking water supply of the households.

The experimental design process
The core of the stated preference technique is statistically characterized by the design of games with hypothetical alternatives to be presented to respondents. Orthogonal design is one of the most commonly applied experimental designs. Orthogonality refers to the correlation structure of the design attributes, where designs with zero correlations are said to be orthogonal; in other words, this guarantees that respondents will be exposed to attributes that vary independently from one another (Sanko 2001). Under this definition, each attribute of the design will be independent of all other attributes,

Table 2 A sample elicitation

Section 3—Elicit willingness-to-pay values: DCE scenario presented to the downstream community members as a valuation scenario for Ecosystem-Based Water Supply Management (EBWSM) in the Dire-Legedadie reservoirs. (Note to the Interviewer: read the following introduction to the respondents very clearly.)

You have been randomly chosen from the residents of Addis Ababa to be involved in this survey. There is a large gap between the supply and demand for potable water in Addis Ababa in addition to the high risk of water contamination. This is mainly attributed to the increasing population growth rate in the city, natural resource degradation across the upstream catchments, which is leading to siltation in the reservoirs, and the poorly managed pipelines and water distribution systems, which is demonstrated by leakage and loses. The provision of improved water service requires proper management of both the water source and supply systems. We want to explore the residents' preferences for EBWSM interventions to improve the ecosystem health of the upstream catchments (Dire-Legedadie reservoir catchments) to increase the quality and quantity of drinking water supplied to the city. Please consider the following two EBWSM interventions.

Improvement of water quality status supplied by the municipality: The raw water quality in the Dire-Legedadie reservoirs has deteriorated over the past several years (greater than 1600 Formazin Turbidity Units; FTU) due to transportation, deposition, and building up of silt, suspended solids, pathogens, and chemicals such as pesticides, chemical fertilizers, and other pollutants from the upstream catchment to the reservoirs. This will cause degraded raw water quality and will significantly increase the cost of raw water treatment. The effectiveness of water treatment becomes burdensome due to increased costs and makes the drinking water unsafe and risky. However, the raw water quality can be improved through appropriate upstream catchment management alternatives, which can reduce costs and make further water treatment more effective. Appropriate upstream catchment management alternatives may include reinstatement of riparian ecological conditions by establishing buffers along rivers and reservoirs, the application of conservation agriculture with controlled grazing, managing waterways through grass filter strips and reforestation activities on degraded lands. Enhancing water quality through upstream catchment management alternatives will also reduce the burden on the municipality with regard to water quality treatment. And it provides an opportunity to focus on the distribution management systems (e.g., regulate and control the distribution system, maintain and replace old and leaky pipelines) and thus reduce the risk of water contamination, which will make the drinking water risk-free and have a high quality.

Enhancement of water quantity and pressure to be supplied by the municipality: Sedimentation and siltation in the Legedadie reservoir have consistently reduced the live storage capacity of the reservoir, which influences the water quantity. Nevertheless, upstream catchment management can be performed through EBWSM interventions (afforestation and reinstating riparian ecological conditions via buffering along streams and reservoirs). These interventions will increase the drinking water supply for the city by means of decreasing the siltation rates and increasing the reservoir's storage capacity. Moreover, upstream catchment management can increase the effectiveness of water recharge and infiltration, which improves the capacity of the groundwater reserves in the Akaki wellfields. This will in turn help to ensure the sustainability of the water supply systems in Addis Ababa. In addition, managing the distribution systems will help to prevent the unnecessary wastage of drinking water through leakage. Therefore, the existing disparity between the water supply and demand can be improved significantly, and water would be available in your house without shortages and at a higher pressure for drinking, showering, washing dishes, and doing laundry at the same time. However, such changes in water improvement will incur additional costs for the execution of the management alternatives that focus on upstream water supply enhancement, which are costly to implement by the municipality or water agency alone. Rather, such programs would be effective if adequate funds are produced through a contribution by the community. Hence, for such an improved water supply scheme, you

Table 2 A sample elicitation (Continued)

would be required to pay a certain amount of money with your monthly water bills. To determine your WTP for these interventions, a monetary value for the improved water supply (i.e., drinking water quality and quantity) in Ethiopian ETB per month is also included in the choices.

Are you willing to pay a certain amount toward the EBWSM interventions? 1. Yes, 2. No (if No, proceed to Q. 62)

Would you participate and go to meetings and workshops to discuss your views on the EBWSM options?

1. Yes, I would be very interested and would attend meetings and workshops to discuss the EBWSM options.

2. No, I would not attend meetings and workshops to discuss the EBWSM options because I do not have time to do so.

3. No, I do not think we need a new water supply system. I am happy with my current water supply situation.

4. No, I would not attend meetings and workshops because I do not believe that an improved system will be built.

5. No, I would not attend meetings and workshops because it is the responsibility of the government to provide water for free.

6. Other
reasons_____?

although some orthogonal designs assume orthogonality only for attributes within alternatives but not between them. The result is that the effect of each attribute level on the responses is more easily isolated. This avoids "multicollinearity" between attributes, which is a common problem with revealed preference data (Sanko 2001). Details of the CE that we used are described elsewhere, and we provide only a brief overview. The attributes and attribute levels (Table 1) were based on a review of the literature (Xiong et al. 2018), initiatives of new local water improvement plans (AAWSA 1994; AAWSA 2004; AAWSA 2011), and expert opinions.

The experimental design presented in this study is a full factorial design that uses every possible combination of attribute levels. The number of combinations is the result of the number of levels raised to the power of the number of attributes. The raised values are simply multiplied when attributes with different numbers of levels are included (Sanko 2001). Thus, the combination of all attributes and levels results in a full factorial experimental design, which gives $2^2 * 1^1 * 6^1 = 24$ different EBWSM alternatives (a design with 2 two-level attributes, 1 one-level attribute, and 1 six-level attribute would have 24 scenarios).

Thus, an orthogonal full factorial design with 24 scenarios with 8 choice sets was created. For a meaningful study, it is usually not possible to administer such a large number of choice sets (Hanley et al. 2006; Lusk and Norwood 2005). Hence, the choice sets or games are randomly assigned to two groups. Each respondent was given four choice sets with three alternatives in each choice set, including the status quo option. The survey

started with a short introduction of the purpose and a description of the attributes, their levels, the choice tasks, and follow-up questions. Three statistical software packages were used in this study. The JMP statistical software (SAS extension) was used to design the combined attribute level scenarios of the experiment in the full factorial design, SPSS (version 21) was used for the data encoding and manipulation, and Stata (version 14.2) was used to estimate the mixed logit WTP-space model.

The *D*-optimality criterion is applied, which is the most popular optimality criteria used to design DCEs. The *D*-optimal choice designs for two-level attributes of any choice set size stem from the work of Burgess and Street (2003), which was extended to apply to attributes with any number of levels by Burgess and street (2005). The *D*-optimality criterion seeks to maximize the determinant of the information matrix in an equation or to minimize its inverse, which is the determinant of the variance-covariance matrix of the parameter estimators. The *D*-optimality criterion considers the covariance. The *D*-criterion value is

$$D_B = \int_{Rk} \left\{ \, det\left(I^{-1}(X,B)\right) \right\}^{\frac{1}{k}} \pi(\beta) d\beta$$

where the exponent 1/k can ensure the independence of the dimension k of the parameter vector b. Minimizing this value results in the *D*-optimal design.

The current status (status quo option) was included in all of the choice sets; this allowed the respondent to not select any of the alternatives provided, which would help to identify the potential to improve the water supply system. The inclusion of the status quo option in the choice sets is also instrumental to achieve welfare measures that are consistent with demand theory (Bateman et al. 2002).

Soon after completing the survey, information about the reasons for objection was gathered from protest respondents through a follow-up question. The purpose was to determine the protest bids (i.e., situations in which the respondents do not agree with the context of the valuation scenarios; in these cases, their stated zero WTP may not be a reflection of their true WTP). However, once the survey was completed, the protest responses and status quo choices were eliminated from further analysis, as suggested by Windle and Rolfe (2013).

Data
We use the stated-preference data collected from the downstream water users of Addis Ababa (AAWSA customers) in 2015 to identify which water supply option (outcome) the respondents prefer the AAWSA to deliver. Four choice sets with 3 alternative water supply choices, including the reference scenario (Table 3) and

11 specific water attributes, were presented to 322 respondents. In addition, the households were asked to provide various sociodemographic characteristics and respond to follow-up questions. A total of 27 responses (8.4%) were identified as protest responses and status quo choices. Hence, the remaining 295 responses were included in the choice modeling analysis.

To ensure sample representativeness, we reviewed several studies on sample size determination in addition to conducting a pilot survey on 53 sample households to understand the context of the study population. The study population is homogeneous with regard to the water shortage problems they are facing and somewhat homogeneous in their sociodemographic characteristics. Based on empirical experience, Lancsar and Louviere (2008) indicated that more than 20 respondents per version of a questionnaire is rarely required for a reliable model estimation. Performing a significant post-hoc analysis to identify and estimate covariate effects may require a larger sample size. However, model estimation with large numbers of alternatives remains computationally expensive. Pearmain and Kroes (1990) proposed that for DCE designs in modeling preference data, the rule of thumb is that sample sizes greater than 100 can provide a basis for obtaining a reliable estimate. Moreover, in the context of a mixed logit model, limiting the number of alternatives in the estimation by simple random sampling yields consistent parameter estimates (Lemp and Kockelman 2012). Thus, we assume that the sample size is representative of the study population.

The survey elicited information about the respondents' overall purchasing behavior and attitudes toward the drinking water supply (Table 2). It also asked whether the respondents would be willing to pay a certain amount per year to support water supply improvement efforts. In addition to the WTP elicitation questions, the survey included questions about various sociodemographic characteristics as well as the existing water demand and supply conditions of the households, which must be included in the DCE analysis.

The various combinations of water quality, quantity, and pressure in different standards were labeled as a binary option. Regardless of whether the household picked choice 1 (0–1 dummy) or choice 2 (0–1 dummy), the price of an alternative is fixed depending on the supply option the respondents chose.

Mixed logit WTP space model
WTP measures have been considered valuable for many reasons. First, by providing information about how people value goods or services, they can directly inform policymakers and thus suggest the pricing of these goods or services (Hanley et al. 2006). Second, in economic evaluations (e.g., cost-benefit analyses), WTP measures

Table 3 A sample choice set

Ecosystem attribute	Pictures explaining attributes	Choice 1	Choice 2	Status quo
Improvement of water quality to be supplied by the municipality		Moderate water quality but drinkable	Risk-free and high-quality water for drinking	High risk of contamination
Enhancement of water quantity to be supplied by the municipality		One month of shortages annually (2-3 days month^{-1})	No months of shortages annually	Two - three months of shortages annually (1 week month^{-1})
Enhancement of water pressure to be supplied by the municipality		Normal pressure (40 to 55 PSI)	Normal pressure (40 to 55 PSI)	Unpredictable and either very low or very high pressure
Compensation to be paid with the monthly water bill (in ETB/month)		12.50	29.00	0
		Choice 1 ☐	Choice 2 ☐	Status quo ☐

insight as an important contribution (Loomes 2001; Oliver 2002; Negrín et al. 2008). Third, a measure of WTP can be a suitable tool for relative comparisons and to determine the levels of interest of consumers for goods and services.

WTP measures can be derived from discrete choice models, which are estimated using either DCE data or revealed preference data. Therefore, the WTP for an alternative attribute is computed as the ratio of the attribute coefficient to the price coefficient (Petrin and Train 2003). Mixed logit models are a state-of-the-art tool applied in the analysis of discrete choices, and they are increasingly being applied in economics (Hall et al. 2006; Lancsar et al. 2007; Regier et al. 2009; Hole 2008; King et al. 2007; Patterson and Hardy 2008; Negrín et al. 2008; Özdemir et al. 2009). Any discrete choice random utility model can be estimated by an appropriately specified mixed logit model (McFadden and Train 2000) due to the possibility of constituting heterogeneity in preferences that are distinct from the observed characteristics.

In a mixed logit model estimate, the distribution of preferences stipulated by the researcher follows a certain distribution, such as a normal distribution (Hole and Kolstad 2012). The distribution parameters (e.g., the standard deviation and the mean in the case of a

normal distribution) are then estimated using either classical or Bayesian estimation techniques. Because the WTP for an attribute is given by the ratio of the attribute coefficient to the price coefficient, the WTP from a mixed logit model is given by the ratio of two randomly distributed terms (Hole and Kolstad 2012). Subject to the choice of coefficient distributions, this can lead the WTPs to have a heavily skewed distribution, and it may not have a defining moment (Hole 2008). A common approach to address this potential problem is to specify the price coefficient to be fixed. This is a convenient assumption, in which the distribution of the WTPs for an attribute is just the distribution of the attribute coefficient scaled by the fixed price coefficient (Hole 2008). However, it is often unreasonable to assume that all individuals have the same preferences for the price (Meijer and Rouwendal 2006), so this approach implies an undesirable balance between the modeling suitability and reality.

A log-normally distributed price coefficient stipulation is another method that allows the price preferences to be heterogeneous. The price coefficient is constrained to be positive, which ensures that the WTP measures have defined moments, but the resulting WTP distribution can be highly skewed, which may produce unrealistic

estimates of the means and standard deviations of the WTP (Hole and Kolstad 2012).

A convenient method to address this problem is to estimate the mixed logit model in the WTP space (Hole and Kolstad 2012) rather than in the preference space, as suggested by Train and Weeks (2005). This method involves direct estimation of the WTP distribution by reformulating the model, in which the coefficients represent the WTP measures. In other words, direct estimation of the WTP by reformulating the mixed logit model is possible by placing estimated parameters representing the WTP distribution rather than the usual coefficients, which they call the WTP space in contrast to the conventional WTP preference space method (Train and Weeks 2005).

Thus, the researcher can make a prior inference about the WTP distribution rather than about the coefficients of the attribute (Hole and Kolstad 2012). The WTP space enables researchers to directly stipulate the WTP distribution and avoids the subjective choice of the WTP distribution that is incurred from the procedure that divides the coefficients of the nonmonetary attributes by the cost coefficient in the WTP preference space approach. This is one of the major advantages of the WTP space over the WTP preference space, and this method has been found to produce more realistic WTP estimates (Hole and Kolstad 2012). Therefore, in this study, we applied a maximum simulated likelihood (MSL) mixed logit WTP space model to estimate the households' WTP for improved water supply.

Model specification
MSL mixed logit WTP space model
In this section, we begin with the conventional design of the utility in the preference space and describe the implications for the correlation of the utility coefficients and the implied WTPs. We then reparametrize the model in the WTP space and discuss the implications.

The utility of person n, which in this case is the water user, derives from choosing a water supply option indexed by j in choice situation t and is specified as a function of the price, w_{njt}, and other nonmonetary attributes of the water supply choices, x_{njt}:

$$U_{njt} = \propto_n w_{njt} + \beta\prime_n x_{njt} + \varepsilon_{njt} \qquad (1)$$

where α_n and β_n are individual-specific coefficients that vary randomly over the water users for the choice option and the other attributes of the choice option, and ε_{njt} is a random term (Gumbel-distributed). We assume that ε_{njt} is extreme value-distributed with a variance given by Var $(\varepsilon_{njt}) = \mu_n^2(\pi^2/6)$, where μ_n is an individual-specific scale parameter for water user n. Train and Weeks

(2005) show that dividing equation Eq. 1 by the scale parameter μ_n to obtain its scale-free equivalent does not affect its behavior because the utility is ordinal. However, this results in a new error term that has the same variance for all decision-makers, which is independent and identically distributed (IID) type-one extreme value-distributed with a constant variance equal to ($\pi^2/6$). The utility coefficients are defined as $\lambda_n = \alpha_n/\mu_n$ and $c_n = \beta_n/\mu_n$, so the utility may be written as follows:

$$U_{njt} = \lambda_n w_{njt} + C\prime_n x_{njt} + \varepsilon_{njt} \qquad (2)$$

Note that if μ_n varies randomly, the utility coefficient λ_n and c_n will be correlated because μ_n is in the denominator of each coefficient. Therefore, specifying the utility coefficients to be independent implicitly constrains μ_n to be constant, implying that the random term is homoscedastic, which may not be a realistic assumption (Louviere et al. 2002). If the scale parameter varies and α_n and β_n are fixed, the utility coefficients also vary with perfect correlation. If the utility coefficients have a correlation less than unity, then α_n and β_n inevitably vary in place of, or in addition to, the scale parameter. Even if μ_n does not vary over the water users (e.g., the standard deviations of the unobserved factors, oversupply option and use are the same for all users), the utility coefficient can be correlated simply due to the correlations between the tastes for various attributes. Train and Weeks (2005) call this specification the model in the preference space. The implied WTP for the water supply attribute is the ratio of the attribute's coefficient to the price coefficient: $\gamma_n = c_{n/} \lambda_{n} = \beta_{n/} \alpha_{n.}$ Because the WTP for the attributes is given by $\gamma_n = c_n/\lambda_n$, Eq. 2 can be rewritten as follows:

$$U_{njt} = \lambda_n \left[\omega_{njt} + \gamma\prime_n x_{njt} \right] + \varepsilon_{njt} \qquad (3)$$

Train and Weeks (2005) call Eq. 3 the WTP space model, and it is also called the "surplus model" by Sonnier et al. (2007). Models (2) and (3) are behaviorally equivalent, but the key point is that standard assumptions about the distributions of λ_n and c_n in the preference space model can lead to unusual WTP distributions. For example, assuming that λ_n and c_n are normally distributed implies that γ_n is a ratio of two normal distributions, which does not have clear moments. This is an unlikely choice of distribution if we were to directly specify the distribution for the WTP, as we do in the WTP space model. In the WTP space specification, the scale parameter is incorporated in the price coefficient λ_n, whereas it cancels out in the expression for the WTP coefficients. Greene and Hensher (2010) show that the WTP space model can be expressed as a distinct instance of the generalized multinomial logit model proposed by Fiebig et al. (2010).

In this study, we estimate the WTP for the water sup-
ply attributes using the WTP space model. Normally,
the coefficients in WTP space models can be estimated
using maximum simulated likelihood or Bayesian
methods (Train 2009). In this paper, we followed the
model estimate using MSL of Thiene and Scarpa (2009).
We compute the WTP space from three alternative
mixed logit models (fixed, uncorrelated, and correlated)
by varying the distribution of the alternative invariant
(case-specific) and alternative variant (alternative-speci-
fic) regressors of the independent variables.
Case-specific variables vary only among the cases,
whereas the alternative-specific variables vary among the
alternatives (as well as the cases). We selected five
case-specific (dysentery, piped water, education, vendor,
and income) and six alternative-specific (price, pressure,
quality, interruption, shortage, and quantity) variables.
Because the attribute coefficients are assumed to be ran-
dom, the model allows a random scale; hence, the price
coefficient is assumed to be log-normally distributed.

The first model is the fixed model, which specifies
fixed WTP coefficients for all of the alternative variant
variables and most of the alternative invariant variables
(i.e., pressure, quantity, quality, interruptions, dysentery,
piped water, education, and shortage), normal distribu-
tion WTP coefficients for some alternative invariant re-
gressors (i.e., income and vendor), and log-normally
distributed coefficients for the price. The second model
is an uncorrelated model, which specifies normally dis-
tributed WTP coefficients for all of the alternative in-
variant and some selected of the alternative specific
regressors (i.e., pressure and interruptions) and
log-normally distributed coefficients for the price and
selected alternative variant regressors (i.e., quantity,
quality, and shortage). The third model is a correlated
model, which allows correlations between the selected
alternative variant/invariant random variables related to
monthly income, paying for water from vendors and
water shortages, and with the price coefficient and with
each other. All of the commands and the method that
the variables (alternative invariant/variant) were entered
into the assumed utility equation are based on MIXLO-
GITWTP (Hole 2016). For detailed information about
the commands, see the description of the commands
and syntax for MIXLOGITWTP in the declaration
section.

Results and discussion
Descriptive statistics
The socioeconomic characteristics of the downstream
resource users involved in the survey are presented in
Table 4. The respondents had lived in the city for be-
tween 1 and 70 years and had ages of 20 to 80 years with
an average age of 45 years. Of the households, 48% were

male-headed, and the remaining 52% were
female-headed, of which 70% were married. Approxi-
mately 66% of the surveyed household heads were first
degree and above in education, and 52% were employed
permanently and thus have sustained means of income.
The monthly incomes in the sample ranged from 2703
to 19,643 ETB with an average of 5592 ETB. The house-
holds were also asked to describe and label their stand-
ard of living; 67% believed their current living conditions
are worse than 10 years ago due to the increasing cost of
living, whereas 33% believed that their current living
conditions are better than 10 years ago. Approximately
94% of the households had an installed piped water sys-
tem at home, whereas the remaining 6% access water
from other sources.

Approximately 58% of the households were living in
their own house, approximately 99% have a latrine facil-
ity, and 94% have piped water installed. The households
were also assessed in terms of their overall water supply
satisfaction, including taste, water quality, and pressure.
Table 4 shows the perceptions of the surveyed house-
holds toward the overall water supply. On average, 49%
of the households were dissatisfied with the water supply
system. Similarly, 50% of the surveyed households were
unhappy with the water availability (quantity), and 51%
were unhappy with the water quality. The surveyed
households had been living in the area for an average of
more than 35 years. Approximately 14% of the respon-
dents had encountered dysentery over the previous
12 months, and only 43% of the respondents believed
the supplied water is risk-free. The surveyed respondents
were willing to contribute an average of 150.5 ETB as a
one-off lump sum payment to kick off the EBWSM ac-
tivities. Similarly, 78% were willing to pay a certain
amount of money monthly toward EBWSM intervention
programs. Generally, 70% of the households want the
AAWSA to continue managing the proposed water
management and supply system.

Empirical findings
Fitting WTP space models
The salient characteristic of the WTP space model is
that the estimated parameters are also the parameters of
the indirect WTP distributions. Table 5 shows the esti-
mation results (coefficients) for the three models (fixed,
uncorrelated, and correlated) in the WTP space. The es-
timate for each parameter is the mean and variance of
1000 draws, and the standard error for a measure of the
statistical accuracy of an estimate is the standard devi-
ation of the distribution (Petrin and Train 2003). The es-
timates given in Table 5 for the three models are the
means and variances of the coefficients, which makes
direct interpretation difficult. Hence, Table 6 gives the
means and standard deviations of the coefficients based

Table 4 Descriptive statistics for the variables used in this study: mean and standard deviation (SD)

Variables	Description	Mean	SD	Min	Max
Age	Age of the household head	45.32	15.23	20	80
Head	= 1 if the household head is male and zero otherwise.	0.48	2.74	0	1
Marital status	= 1 for those who are married and zero otherwise	0.70	0.45	0	1
Family size	Number of household members or family size	5.42	2.62	1	21
Living	Number of years the household has lived in the town	35.32	15.41	1	70
Housing	= 1 if households possess own house and zero otherwise	0.58	0.51	0	1
Education	Household head's education level (from illiterate to advanced degrees)	5.491	1.87	1	9
Employment	= 1 if the household head is permanently employed and zero otherwise	0.52	0.49	0	1
Income	Average monthly income of the household (in 000)	5.592	2.59	2.703	19.643
Standard of living	= 1 if the household's standard of living has improved compared to 10 years ago and zero otherwise	0.33	0.47	0	1
Latrine facility	= 1 if the household has an installed private latrine facility at home and zero otherwise	0.99	0.233	0	1
[Piped water]	= 1 if the household has installed piped water at home and zero otherwise	0.94	0.234	0	1
[Taste of water]	= 1 if household is satisfied by the taste of the water provided by the source and zero otherwise	0.49	0.500	0	1
[Interruptions/water cut]	Number of water-cut days per week	2.25	1.156	2	6
[Shortage]	Hours of the day that the household often experiences water shortages	10.57	6.965	2	24
[Travel time]	Walking or travel time to the water point and back in minutes	1.10	0.415	1	2
[Dysentery]	= 1 if the household has faced dysentery over the past 12 months and zero otherwise	0.14	0.350	0	1
[Satisfaction]	= 1 if the household is satisfied by the overall water supply system and zero otherwise	0.51	0.513	0	1
[Health risk]	= 1 if the household believed that the supplied water is risk-free and zero otherwise	0.43	0.495	0	1
[Vendor]	=1 if the household purchases water from vendors and 0 otherwise	0.15	0.35	0	1
[Participation]	= 1 if the household is willing to participate in meetings and workshops on water supply issues and zero otherwise	0.67	0.468	0	1
[Management]	= 1 if the household prefers the AAWSA to manage the improved water supply and zero otherwise	0.70	0.460	0	1
Quality	= 1 if the household has access to risk-free standard quality water for drinking and cooking daily and zero otherwise	0.49	0.500	0	1
Quantity	= 1 if the household has access to enough water for drinking and cooking daily and zero otherwise	0.50	0.500	0	1
Pressure	= 1 if the water pressure is below normal (40–55 PSI) and zero otherwise	0.498	0.500	0	1
Price	Payment options for available alternatives	23.51	7.64	12.5	36
WTP	= 1 if the household is willing to pay for EBWSM interventions and zero otherwise	0.78	0.415	0	1
Contribution	One-off lump sum kickoff payment in ETB (tens) by the household for source watershed management activities	150.55	472.92	0	2000
	Valid N (listwise)	295			

NB: sociodemographic variables (italic), specific water attributes (bracketed), bundle choice option (bold) and payment variables (normal)

on the estimates of Table 5. Results with a mean and standard deviation simplify explanations by providing summary information about the estimates (Petrin and Train 2003), and the estimates generally appear to be convincing.

The WTP space models indicate that allowing for full correlation between the coefficients increases the trend of the simulated log-likelihood at convergence for the estimation means from the mixed (– 184.99) and uncorrelated (– 184.97) models to the correlated (– 183.20) model; thus, the values of simulated log-likelihoods are improved from – 196.30 to – 183.20. The estimated means have the same signs and orders of magnitude across the models (with and without correlation) and estimates of MSL. Negative means are observed for single attributes rather than for a bundle of choices. Considering the sign of the utility parameter (estimate), a

negative sign indicates that an increase in the variable makes the average customer worse off (decreases their utility as well as the WTP space), whereas a positive sign indicates that an increase in the variable make the average customer better off (increases their utility as well as the WTP space). The signs of these estimates are consistent with our expectations.

Low pressure, the frequency of water cuts or interruptions per week, the frequency of dysentery, lack of access to piped water, a continuous water supply from vendors, extended time of the day that households faced water shortages, and higher prices make the average consumer worse off (Table 6). In contrast, a household's access to sufficient water (i.e., quantity), risk-free and standard water quality, and access to installed piped water all make the average consumer happier (better off).

Table 5 Estimated coefficients (means and variances) of the three models in the WTP space

Attribute	Parameter	Fixed		Uncorrelated (log-normal)		Correlated (random)	
		Estimate	Std. Err	Estimate	Std. Err	Estimate	Std. Err
Choice 1	Mean of Coeff.	27.02	0.135	27.00	0.135	28.05	0.140
	Variance of Coeff.	5.38		5.37		5.82	
Choice 2	Mean of Coeff.	27.96	0.326	27.48	0.387	32.25	0.403
	Variance of Coeff.	31.29		44.17		47.81	
Pressure	Mean of Coeff.	− 1.73	0.077	− 1.76	0.078	− 1.52	0.072
	Variance of Coeff.	1.74		1.79		1.51	
Quantity	Mean of Coeff.	2.94	0.077	2.92	0.078	2.72	0.074
	Variance of Coeff.	1.75		1.80		1.62	
Quality	Mean of Coeff.	5.48	0.097	5.51	0.098	5.45	0.096
	Variance of Coeff.	2.77		2.82		2.69	
Interruption	Mean of Coeff.	− 1.66	0.056	−v1.64	0.058	− 1.59	0.066
	Variance of Coeff.	0.93		0.98		1.29	
Dysentery	Mean of Coeff.	− 0.98	0.056	− 0.96	0.057	− 0.93	0.063
	Variance of Coeff.	0.91		0.95		1.16	
Piped water	Mean of Coeff.	0.81	0.064	0.82	0.064	1.56	0.076
	Variance of Coeff.	1.19		1.21		1.68	
Education	Mean of Coeff.	1.56	0.056	1.54	0.058	1.58	0.066
	Variance of Coeff.	0.93		0.98		1.29	
Vendor	Mean of Coeff.	− 0.17	0.499	− 0.43[a]	0.421	− 1.00	0.605
	Variance of Coeff.	0.01		0.00[b]		1.00	
Income	Mean of Coeff.	8.43	0.144	8.55[a]	0.152	9.07	0.037
	Variance of Coeff.	0.00		4.82[b]		2.69	
Shortage	Mean of Coeff.	− 1.75	0.086	− 1.76[a]	0.087	− 2.88	0.115
	Variance of Coeff.	0.01		0.00[b]		7.54	
Price	Mean of ln (Coeff.)	− 0.14[a]	0.018	− 0.14[a]	0.018	− 0.27[a]	0.244
	Std. dev. of ln (Coeff.)	0.02		0.02		0.52	
SLL at convergence		− 184.99		− 184.97		− 183.20	
No. of iterations at convergence		3		7		8	

[a]Mean of ln (coefficient)
[b]Variance of ln (coefficient)

Therefore, all other things being equal, the respondents prefer a bundle of supply options with risk-free and high-quality water at normal pressure (40 to 55 PSI) with no months of shortages in all of the models. They prefer access to sufficient water daily rather than occasionally insufficient water supply as well as access to risk-free and standard quality water for drinking and cooking rather than water with questionable quality that is potentially risky. In terms of disease, they prefer to be free from incidents of dysentery. In addition, they prefer to have piped water and an uninterrupted water supply. Surprisingly, a water supply by a vendor that mitigates most of the water shortages is not preferred by households, perhaps because the provision of water by vendors might be more expensive than water provided by

the agency. Households prefer no extended water shortages during the day. The coefficients for the dysentery, piped water supply, and vendor supply attributes are insignificant in all of the models.

Fixed WTP space model

According to the coefficients and WTPs of the model's bundle options, on an "all other things equal" basis, high WTP is associated more with choice 2 than with choice 1; hence, households are more likely to be willing to pay for choice 2 over choice 1. Choice 1 has an estimated mean of 27.02 and an estimated standard deviation of 2.319. Therefore, 0.5% of the distribution is willing to pay less than 21 ETB, and 99.5% is willing to pay more than 21 ETB, of which approximately 49.1% is willing to

Table 6 Estimated coefficients (means and standard deviations) of the three models in the WTP space

Attribute	Fixed		Uncorrelated (lognormal)		Correlated (random)	
	WTP		WTP		WTP	
	Mean	SD	Mean	SD	Mean	SD
Choice 1	27.01557	2.319	27.002	2.318	28.053	2.412
Choice 2	27.95799	5.593	27.478	6.646	32.251	6.914
Pressure	− 1.72804	1.319	− 1.758	1.340	− 1.518	1.229
Quantity	2.944709	1.324	2.924	1.340	2.720	1.273
Quality	5.479457	1.665	5.508	1.680	5.448	1.641
Interruption	− 1.66327	0.967	− 1.637	0.991	− 1.591	1.137
Dysentery	− 0.9824	0.954	− 0.957	0.975	− 0.929	1.078
Piped water	0.813201	1.092	0.815	1.098	1.563	1.297
Education	1.56327	0.963	1.537	0.989	1.581	1.137
Vendor	− 0.16659	0.077	− 0.432	0.019	− 0.997	1.000
Income	8.426616	0.045	8.551	0.024	9.071	1.640
Shortage	− 1.75488	0.095	− 0.172	0.005	− 2.883	2.746
Price	− 0.872	0.110	− 0.882	0.174	− 0.781	0.146

pay between 21 and 27 ETB, and 49.9% is willing to pay between 27 and 33 ETB. The number of households willing to pay more than 33 ETB is 0.5% of the distribution, which is not surprising considering that the choices and WTP are sensitive to and associated with service quality, price, and household income. Based on the WTP distribution, this alternative has the smallest number of households that are willing to pay the maximum price option and the largest share of households that are willing to pay between 27 and 33 ETB.

Choice 2 has an estimated mean of 27.96 and an estimated standard deviation of 5.593. This corresponds to 10.75% of the distribution being willing to pay less than 21 ETB and 89.25% being willing to pay 21 ETB. Approximately 32.5% of the distribution is willing to pay between 21 to 27 ETB, 38.34% is willing to pay between 27 and 33 ETB, and the remaining 18.41% is willing to pay more than 33 ETB. Like choice 1, this alternative also has the largest share of households that are willing to pay between 27 and 33 ETB. In contrast, choice 2 includes a relatively large number of respondents whose WTP is focused on the extreme price option.

Uncorrelated WTP space model

As specified in the WTP space model, the uncorrelated model has a random coefficient for each variable, and the WTPs are assumed to be uncorrelated over the attributes. We estimated a model with the utility specified as in Eq. 3, where the coefficient of each nonprice attribute is the product of the WTP for that attribute times the price coefficient (Hole and Kolstad 2012), and the model allows for a random scale.

The price coefficient $-\lambda_n$ is given an independent lognormal distribution. The elements of ω_n (WTPs) associated with the cost of the vendor-supplied water, water shortage, and household income are also specified to be independently lognormal. These variables are expected to have the same sign for all of the respondents with only their magnitudes differing over respondents. Specifying a coefficient to be log-normally distributed implies that the WTPs for all individuals are positive, but negative WTPs are managed by entering the attribute multiplied by − 1 in the model (Hole 2016). The mean and variance of the log of the coefficient are estimated, and the mean and standard deviation of the coefficient itself are calculated from these estimates. The coefficients of ω_n associated with choice 1, choice 2, pressure, quantity, quality, interruption, dysentery, and piped water are instead given independent normal distributions with means and variances that are predicted. The simulation was performed using 1000 Halton draws for each sampled respondent. In this case, however, the chosen distributions for the nonmonetary attributes represent the WTP distributions for these attributes. When the WTPs are normally distributed for an attribute and the price coefficient is lognormal, the coefficient of the attribute is not normal (Petrin and Train 2003). Moreover, due to the common influence of the price coefficient on the other coefficients, an uncorrelated WTP implies correlated coefficients (Petrin and Train 2003).

For the bundle options, similar to the fixed model, the distribution of the coefficients in the uncorrelated WTP space model indicates that the respondents placed a higher value on choice 2 over choice 1. Choice 1 has an estimated mean of 27 and an

estimated standard deviation of 2.32. Like the fixed model, 0.5% of the distribution is willing to pay less than 21 ETB, and 99.5% is willing to pay more than 21 ETB, of which approximately 49.5% is willing to pay between 21 and 27 ETB, and 49.5% is willing to pay between 27 and 33 ETB. WTPs greater than 33 ETB represent 0.5% of the distribution, which is not surprising because in most cases, the choices of services provided (i.e., water) and WTP are sensitive to and associated with service quality, price, and income. In this choice alternative, the distribution of WTP therefore includes the smallest number of households that are willing to pay the maximum price option and the largest share of households willing to pay between 21 and 33 ETB.

Choice 2 has an estimated mean of 27.45 and an estimated standard deviation of 6.45. This corresponds to 16.5% of the distribution being willing to pay less than 21 ETB, and the remaining 83.5% is willing to pay more than 21 ETB. When considering the lowest price alternative, approximately 0.5% of the distribution is willing to pay less than 12.5 ETB, and 99.5% is willing to pay more. Nearly 33.4% of the distribution is willing to pay between 21 and 27 ETB, and 29.67% is willing to pay between 27 and 33 ETB. Approximately 20.32% of the distribution is willing to pay more than 33 ETB. Surprisingly, this alternative includes a relatively significant number of respondents with WTP for the extreme price option.

Correlated WTP space model

For both choices, the results of the model with correlated coefficients have the highest means (28.05 for choice 1 and 32.25 for choice 2) with the fewest households that prefer to pay the least (0.2% for choice 1 and 5.26% for choice 2). Like the other two models, the respondents placed a higher value on choice 2 over choice 1, which is shown by the distribution of the coefficients. Choice 1 has an estimated mean of 28.05 and an estimated standard deviation of 2.412. Approximately 0.2% of the distribution is willing to pay less than 21 ETB, and 99.8% is willing to pay more than 21 ETB, of which 33.16% is willing to pay between 21 and 27 ETB, and 64.62% is willing to pay between 27 and 33 ETB. Households willing to pay more than 33 ETB represent 2.02% of the distribution.

Choice 2 has an estimated mean of 32.25 and an estimated standard deviation of 5.914, which corresponds to 5.26% of the distribution being willing to pay less than 21 ETB and 94.74% being willing to pay more. Approximately 17.1% of the distribution is willing to pay between 21 and 27 ETB, and 32.02% is willing to pay between 27 and 33 ETB. Those who are willing to pay more than 33 ETB make up approximately 45.62% of the

distribution. In contrast to the other two models and alternatives, the number of respondents whose WTP is for the extreme price option in choice 2 of the correlated model is remarkably large (nearly 46%).

Although all three models are types of mixed logit willingness to pay space models, they all vary in terms of allowing or not allowing random and/or fixed scales, estimations of the simulated log-likelihood at convergence, implied WTP distributions, and how well the model fits the observed data. We use the models to compare the specifications across the three WTP space models. The log-likelihood is considerably higher for the correlated model than for the other two models. The same is true for the WTP distributions; hence, the correlated WTP space model fits the data well and appears to be more reasonable. The main distinction is that the means and especially the standard deviations of the WTPs for the fixed and uncorrelated WTP space models are smaller than those for the correlated WTP space model. The correlations are relatively high because each WTP is multiplied by the common price coefficient. In conclusion, for both the coefficients and WTP values, estimating the distributions after restricting the attributes to be fixed and not allowing them to correlate with selected variables and with each other results in smaller means and standard deviations than when the distributions are estimated by allowing correlations.

Correlations

The correlations between the coefficients of the WTP measures (Table 7) are derived from the correlated WTP space model. The results in the tables show that there is a high degree of correlation between the coefficients of the WTP measures. In particular, the WTP for the water shortage and vendors supply coefficients are correlated negatively with the income coefficient and positively with the price coefficients. The respondent's income and price alternatives are also positively correlated.

The high negative correlations of the income coefficient with shortage and vendor supply suggests that to fill the supply gap (i.e., shortage), households who earn higher incomes may provide themselves with extra water storage tanks, so they are not as dependent on vendors. This may also indicate that lower-income respondents

Table 7 Correlations between the WTP measures and the income coefficient

Rho correlation				
	Income	Shortage	Vendor supply	Price
Income	1			
Shortage	− 0.97	1		
Vendor supply	− 0.72	0.75	1	
Price	0.24	0.30	0.27	1

are unable to secure a supplemental water storage container and hence face water scarcity, which further encourages them to buy water from vendors.

Positive correlations are observed between prices and the water shortage and vendor supply. This suggests that increasing the frequency of water shortages may increase a household's dependence on purchasing from water vendors. This encourages them to make WTP decisions even for higher payment options (price). The price coefficient is positively correlated with income, implying that the WTP of a household increases as their income grows.

Marginal effects: changes in probabilities

The marginal effect estimates the change in the likelihood of an outcome due to a change in x_k while holding all other independent variables constant (Long and Freese 2006). The main idea is that one variable changes while the others do not. For each discrete and continuous variable, the calculated marginal effects are diverse; thus, two varieties of marginal effects are estimated: marginal change and discrete change. A marginal change computes the effect of an instantaneous or infinitely small change in X_k, whereas a discrete change computes the effect of a discrete or finite change in X_k. A marginal change is the rate of change in the likelihood of an infinitely small change in x while other variables remain constant. Because the effect is computed with a partial derivative, some authors refer to this as the partial change or partial effect. In contrast, a discrete change, which is sometimes called a first difference, is the actual change in the predicted probability for a given change in x_k while the other variables are held constant. The discrete change indicates how much the probability actually changes for a given change in a variable.

Long and Freese (2006) showed that if the probability curve used to evaluate a change is approximately linear, the effect on the probability of an outcome of a unit change in the variable will be approximated by the marginal change. The best way to determine how well the marginal effect approximates the change is to compute the discrete change (Long and Freese 2006). Thus, in this study, we examine both the discrete change and the marginal change. Discrete changes of one unit, one standard deviation, from minimum to maximum, and between other percentiles, which indicate the actual changes in the probability for a specific change in x_k, were assessed. For the marginal change, the average marginal change is assessed.

Marginal effects are fundamental for interpreting nonlinear models, especially using m-change, which creates compact tables that contain many types of marginal effects. It is a method to rapidly measure the maximum potential impacts of both factors and continuous variables over the range. Normally, changes are computed as observed; the change for each observation is computed from the estimation sample and then averaged. These are sometimes called average marginal effects. For continuous variables, the rows labeled marginal contain the average marginal changes and are identical to what is computed using margins, dydx(*). For binary factor (categorical) variables, m-change computes the average discrete change as the variable changes from 0 to 1. By default, for continuous variables, m-change also computes two types of discrete changes. The unit change, which is labeled + 1, is the change in the prediction as the variable changes from its observed value to its observed value plus 1 (Long and Freese 2006). The change in the standard deviation, which is labeled + SD, is the change in the prediction as the variable changes from its observed value by one standard deviation. The amount (range) option computes the discrete changes as x changes from its minimum to its maximum, and the trim (#) option can also be used to compute the change between other percentiles.

The descriptive statistics show that the income variable (in thousands of ETB) has a range of approximately 16,940 ETB. Hence, although a unit change (1000 difference in income) is small for describing the effect of income on WTP, it appears to be reasonable given the differences in income. By default, m-change computes discrete changes for both a 1-unit change and a standard deviation change in income, and we use brief to suppress showing the average probabilities. The average predicted probabilities of the households' WTP are 52.05, 47.34, and 60.85 for the fixed, uncorrelated, and correlated model estimates, respectively (Table 8).

While holding the other variables at their observed values, increasing the income by one standard deviation (approximately 2579.00 ETB) increases the probability of the households' WTP by averages of 22.5 (fixed model), 5.8 (uncorrelated model), and 23.6 (correlated model), with all effects significant at the 0.01 level. These results are consistent with those of Hensher et al. (2005), who conclude that income significantly influences households' WTP for improved water services. In contrast, Hanley et al. (2006) reported that poorer groups are willing to give up higher fractions of their income for environmental improvements than richer groups.

An increase of one standard deviation in the log of the anticipated price (approximately 7.64) decreases the probability of WTP by averages of 14.81 (fixed model), 14.79 (uncorrelated model), and 13.42 (correlated model), with all effects significant at the 0.001 level. This result is consistent with the findings of Hensher et al. (2005) that the price elasticity of the demand for water characteristics is normally negative because the demand curve slopes downward, which implies that an increase

Table 8 Marginal effects (m-change, delta option of a five-unit change above the base value and percentile changes) of selected significant parameters

	Fixed		Uncorrelated		Correlated	
	Change	p value	Change	p value	Change	p value
Income						
1	8.179	0.004	2.113	0	8.582	0.005
SD	22.48	0.004	5.808	0	23.588	0.005
Marginal	8.179	0.004	2.113	0	8.582	0.005
Delta(5)	40.895	0.004	10.567	0	42.912	0.005
5% to 95%	58.34	0.004	15.074	0	59.335	0.005
Price						
1	− 1.937	0	− 1.935	0	− 1.756	0
SD	− 14.806	0	− 14.79	0	− 13.423	0
Marginal	− 1.937	0	− 1.935	0	− 1.756	0
Delta(5)	− 9.687	0	− 9.676	0	− 8.782	0
5% to 95%	− 45.529	0	− 45.478	0	− 41.276	0
Education						
1	0.043	0.032	0.055	0.041	0.082	0.02
SD	0.711	0.032	0.903	0.041	1.348	0.02
Marginal	0.043	0.032	0.055	0.041	0.082	0.02
Delta(5)	0.217	0.032	0.276	0.041	0.412	0.02
5% to 95%	1.862	0.032	2.365	0.041	3.529	0.02
Quality						
1	5.464	0.001	5.499	0.001	5.426	0.001
SD	12.966	0.001	13.048	0.001	12.876	0.001
Marginal	5.464	0.001	5.499	0.001	5.426	0.001
Delta(5)	27.321	0.001	27.494	0.001	27.131	0.001
5% to 95%	31.094	0.001	31.29	0.001	30.877	0.001
Quantity						
1	2.936	0.027	2.903	0.031	2.715	0.033
SD	5.09	0.027	5.032	0.031	4.708	0.033
Marginal	2.936	0.027	2.903	0.031	2.715	0.033
Delta(5)	14.68	0.027	14.513	0.031	13.576	0.033
5% to 95%	12.81	0.027	12.664	0.031	11.846	0.033
Average prediction	52.046		47.338		60.847	

in price is expected to decrease the demand. This finding is also consistent with Null et al. (2012), who states that because demand is very sensitive to price, a household's willingness to pay for cleaner water is often less than the cost of supply. This suggests that households prefer lower-cost water supply options.

In addition, increasing the households' educational attainment by one level (e.g., from illiteracy to basic education) increases the probability of the households' WTP by averages of 0.04, 0.05, and 0.08 for the fixed, uncorrelated, and correlated models, respectively. Similarly, increasing the households' educational attainment by one

standard deviation (by approximately two levels, such as from primary schooling to college diploma) increases the probability of the households' WTP by averages of 0.7 (fixed model), 0.9 (uncorrelated model), and 1.35 (correlated model), all of which are significant at the 0.05 level. This may be because the educational level of the households increases their awareness and exposure level, and they will thus be more receptive to a policy that leads to improved livelihood and welfare. This finding is consistent with the results of Haq et al. (2007) and Adenike and Titus (2009), who found that education level has a direct relationship with WTP for safe

drinking water. In addition, Sattar et al. (2007) confirmed that a household's exposure to mass media and formal education substantially affects their WTP for different water-cleaning methods, which demonstrates that the education of the household's decision-maker is a significant determinant of their WTP.

A marginal change and a 1-unit discrete change in a households' monthly income (1000.00 ETB) are associated with increases in the probability of the households' WTP of 8.2, 2.1, and 8.6 in the fixed, uncorrelated, and correlated models, respectively. The marginal change and a unit discrete change in alternative payment options (nearly 2.5 ETB) are associated with 1.94, 1.94, and 1.76 decreases in the probability of households' WTP in the three models, respectively. These results indicate that the marginal change and a unit discrete change are similar, which reflects that the probability curves are nearly linear for a change of 1 in either variable.

In addition to one unit and standard deviation changes, a change in a specific amount was also explored to investigate the relationship and effect on WTP. Hence, a discrete change in a household's monthly income from the base value to five units above the base value (approximately 5000.00 ETB) is computed using the delta option in m-change (i.e., delta 5). A 5000 ETB change in a household's monthly income is associated with average increases of 40.9 and 43 in the probability of the households WTP in the fixed and correlated models, respectively, and an increase of only 10.6 in the uncorrelated model. A change in the alternative price by five units above the base value of approximately 20 ETB (computed as the average of the difference between consecutive price options multiplied by five units) is associated with decreases in the probability of the households' WTP of 9.7 in the fixed and uncorrelated models and 8.8 in the correlated model.

M-change is a quick way to assess the maximum potential impacts of both continuous variables and factor variables over their ranges (Long and Freese 2006). Changes over the range indicate the expected change in the outcome probability in the unlikely event of large changes in a variable while holding the other variables constant. Although such large changes are unlikely to occur in the real world, it allows the greatest effect to be identified. However, because the range of a variable can be influenced by even a single extreme observation (e.g., one person with an unusually high income), using trimmed ranges for some variables is the best option.

A trimmed range might be more informative for a variable such as monthly income, where only a few households might have very high incomes. Thus, by specifying trim (5), we examined the effect of a change from the 5th percentile of income to the 95th percentile. The effects are substantially higher, most noticeably for the

fixed and correlated models. On average, the probabilities of the households' WTP will increase by 58.3, 15.1, and 59.3 if the respondents changed from the 5th percentile of income to the 95th percentile ($p < 0.01$, two-tailed). On the other hand, the probability of the households' WTP will decrease by 45.5 for the fixed and uncorrelated models and by 41.3 for the correlated model if the alternative changed from the 5th percentile of price to the 95th percentile ($p < 0.001$, two-tailed). Generally, the changes in the predicted probability of a household's WTP are higher for the correlated and fixed models than for the uncorrelated model. We can obtain more information about the discrete changes over the range from the starting to ending probabilities by using the centile on the 5th and 95th percentiles (Tables 9 and 10).

Varying a household's monthly income from the 5th percentile to the 95th percentile (i.e., from 2913 to 10,573 ETB) increases the probability of WTP from 5.1 to 63.5 (an increase of 58.3) for the fixed model (Table 10). With a similar change in a households' monthly income, the probabilities of WTP increase from 48.7 to 63.8 (an increase of 15) for the uncorrelated model and from 1.9 to 61.2 (an increase of 59.3) for the correlated model ($p < 0.005$, two-tailed). The results show that there is a positive relationship between monthly income and WTP, which indicates that the effect of a households' monthly income is positive and highly statistically significant.

Conversely, shifting the price of alternative choices from the 5th to 95th percentile (i.e., from 12.5 to 36 ETB) decreases the probability of WTP from 76.2 to 30.7 (a decrease of 45.5) in the fixed model, from 85 to 39.5 (a decrease of 45.5) in the uncorrelated model, and from 69.3 to 28 (a decrease of 41.3) in the correlated models ($p < 0.00$, two-tailed). Although the discrete change is not significant, the change in household education from the 5th to the 95th percentile (i.e., from basic education to third degree level) increases the probabilities of WTP from 50.5 to 52.4 (an increase of 1.9) in the fixed model, from 58.9 to 61.3 (an increase of 2.4) in

Table 9 The 5th and 95th percentiles of income, price, and education using the centiles

Variable	Obs	Percentile	Centile	Binom. Interp. [95% conf. interval]	
Income	1180	5	2913	2913	3023
		95	10,573	10,463	11,023
Price	1180	5	12.5	12.5	12.5
		95	36	36	36
Education	1180	5	3	3	4
		95	8	7	8

Table 10 Starting and ending probabilities of the discrete changes for the continuous independent variables (income, price, and education) across the three models

		Change	From	To	*p* value
Income					
5% to 95%	Fixed	58.34	5.139	63.48	0.004
	Uncorrelated	15.074	48.727	63.801	0
	Correlated	59.335	1.883	61.218	0.005
Price					
5% to 95%	Fixed	− 45.529	76.234	30.705	0
	Uncorrelated	− 45.478	85.008	39.53	0
	Correlated	− 41.276	69.266	27.99	0
Education					
5% to 95%	Fixed	1.862	50.527	52.389	0.854
	Uncorrelated	2.365	58.917	61.283	0.823
	Correlated	3.529	44.458	47.988	0.753

the uncorrelated model, and from 44.5 to 48 (an increase of 3.5) in the correlated model.

The results confirm the theory of environmental economics, which assumes that the demand for an improved ES increases with consumer income (McConnell 1997). According to Moffat et al. (2011a, b), those with a higher income were willing to pay for a better water supply system. Similarly, in a study at Chongqing in China, Wang et al. (2010) found that greater WTP is correlated with higher-income households than with lower-income households; households with higher incomes have a higher willingness to pay than lower-income households. High-income households also have higher WTP than middle-income households (Khan et al. 2010). Generally, this result is consistent with the argument that if something is worth having, then it should be worth paying for.

In contrast, several studies have found different results. For example, Cairncross (1990) and World Bank (1996) showed that low-income consumers are willing to pay for water supply services. In addition, Chowdhury (1999) used the contingent valuation technique to predict Dhaka slum dwellers WTP for safe drinking water and found that in an effort to manage water supply-related costs, slum dwellers are willing to pay

sufficiently more than others, indicating that to generate funds for water system investment, higher water prices would be financially feasible.

For categorical variables, a household's daily "access to" high-quality water increases the probability of WTP than the opposite "no access to" high-quality water supply. On average, daily access to risk-free high-quality water for drinking and cooking increases a household's probability of WTP from 52 to 65 (an increase of 12.9) in the fixed model, from 60.8 to 73.9 (an increase of 13) in the uncorrelated model, and from 47 to 60 (an increase of 12.9) in the correlated model, with *p* = 0.001 (Table 11). Similarly, a household's daily "access to" water supply adequately increases the probability of WTP more than the opposite "no access to" an adequate water supply. These results show that, on average, daily access to sufficient water for drinking and cooking increases a household's probability of WTP from 52 to 57 (an increase of 5.1) in the fixed model, from 60.1 to 65.9 (an increase of 5) in the uncorrelated model, and from 47 to 52 (an increase of 4.7) in the correlated model, with *p* < 0.05 (Table 11). Generally, the results show that the correlated model fits the data better than the fixed and uncorrelated models.

Conclusion

In this study, we used mixed logit WTP space models to examine downstream household water users' willingness to pay (WTP) for improved access to or quality of drinking water services based on stated preference data collected from 322 households. Downstream water users were exposed to alternative water supply improvement options, including quality, quantity, and pressure. Three models (fixed, uncorrelated, and correlated) were compared.

The results showed that three-quarters of the households are willing to contribute a certain amount of money on a monthly basis toward EBWSM intervention programs. The average contribution that the respondents were willing to pay was 150.5 ETB as a one-off lump sum to kick off the EBWSM activities. This implies that AAWSA customers are willing to pay to avoid most types of water supply restrictions. In addition, more than

Table 11 Starting and ending probabilities of discrete changes for categorical/factor independent variables (water quality and quantity) across the three models

			Change	From	To	*p* value
Quality	Fixed	Access vs no access	12.966	52.046	65.012	0.001
	Uncorrelated	Access vs no access	13.048	60.847	73.895	0.001
	Correlated	Access vs no access	12.876	47.338	60.213	0.001
Quantity	Fixed	Access vs no access	5.09	52.046	57.136	0.027
	Uncorrelated	Access vs no access	5.032	60.847	65.879	0.031
	Correlated	Access vs no access	4.708	47.338	52.045	0.033

70% of the households want the AAWSA to continue managing the proposed water management and supply system.

The empirical results indicated that the majority of respondents chose choice 2 over choice 1, implying that households prefer to be supplied with risk-free, high-quality water without interruption at an appropriate flow pressure. The model with correlations fits the data well with the highest simulated log-likelihoods at convergence and gives the best estimates of households' WTP for water improvement schemes. Nearly 46% of the sampled households were willing to pay more than 33 ETB per month for the monthly water bill, and more than 49% of the households were willing to pay between 21 ETB and 33 ETB per month. Overall, approximately 95% of the households were willing to pay more than 21 ETB.

Generally, household WTP is sensitive to scope (i.e., extent of service improvement linked to potable water), household income, affixed price, and the method of stated preference elicitation. In particular, the demand for improved water services is significantly related to the price of service and income and to some extent to the educational attainment of the households. This suggests that the demand for safe drinking water could be higher if income levels are high. Moreover, like household income, the WTP of well-informed households is higher than that of households that are not informed or less aware of the situation, and if people have sufficient access to information and awareness of the health risks associated with inferior water quality, they are more likely to have a higher WTP. Therefore, increasing awareness about the adverse health effects of unsafe drinking water will increase the demand for an improved drinking water supply. Importantly, the influences of these factors follow the theoretical predictions and intuition. In conclusion, mixed logit WTP-space models can help predict household-level WTP well for selected improvements in drinking water access and services in the Legedadie-Dire catchments.

Abbreviations
AAWSA: Addis Ababa Water and Sewerage Authority; DAAD: German Academic Exchange Service; DCEs: Discrete choice experiments; DEFRA: Department of Environment, Food and Rural Affairs; EBWSM: Ecosystem-based water supply management; EG: Ephrem Gebremariam; EiABC: Ethiopian Institute of Architecture, Building Construction, and City Development; Eq: Equation; ES: Ecosystem services; ETB: Ethiopian Birr; Fig: Figure; FTU: Formazin turbidity unit; GZ: Gete Zeleke; IFS: International Foundation for Science; IID: Independent and identically distributed; IPBES: Inter-governmental Platform on Biodiversity and Ecosystem Services; LEAP: Leadership Enhancement in Agricultural Program; Ln: Log normal; LULCC: Land use and land cover change; mH$_2$O: Meter of water column; Mm^3: Million cubic meters; MPR: Master plan review; MSL: Maximum simulated likelihood; PES: Payment for ecosystem services; PSI: Pounds per square inch; SD: Standard deviations; TEEB: The Economics of Ecosystems and Biodiversity; UK: United Kingdom; USA: United States of America; USD: United States Dollar; WTP: Willingness to pay; YA: Yilikal Anteneh; ZEF: Center for Development Research

Description of some command and syntaxes for MIXLOGITWTP
The post estimation command mixlogitwtp fits mixed logit models in willingness to pay (WTP) space by using MSL based on {cmd:mixlogitwtp} command of (Hole, 2016). All of the {cmd:mixlogit} post estimation commands are available after {cmd:mixlogitwtp}.
The predicted probabilities (both in and out of sample) are calculated by mixlpred command. The coefficient covariance matrix along with their standard errors are calculated by mixlcov command (which is relevant only when the coefficients are specified to be correlated). While the individual-level parameters corresponding to the variables in the specified variable list (both in and out of the sample) are calculated using mixlbeta command. Full command of the variables for the fixed (A), uncorrelated (B), and correlated (C) models:

(A) *mixlogitwtp Y choice1 choice2 Pressure Quantity Quality Interruptions Dysentry12 Piped-water Education Shortage, group (GG) id (id2) Price(mPrice) rand(Income Vendor) nrep(1000) burn(50)*

(B) *mixlogitwtp Y, group (GG) id (id2) Price(mPrice) rand (choice1 choice2 Pressure Interruptions Dysentry12 Piped-water Education Vendor Income Quantity Quality Shortage) ln(3) nrep(1000) burn(50)*

(C) *mixlogitwtp Y choice1 choice2 Pressure Quantity Quality Interruptions Dysentry12 Piped-water Education, group (GG) id (id2) Price (mPrice) rand (Income Vendor Shortage) nrep(1000) burn(50) corr*

Availability of data and materials
Please contact the author for data requests.

Authors' contributions
YA developed the design of the model and the study in total, analyze and evaluated the results, and drafted the manuscript. GZ participated in the study, coordinated and helped evaluation of results. EG participated in the design of the study, managed the database, and helped to draft the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate
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