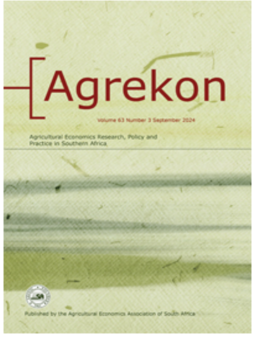

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ABSTRACT

The water use practices in Menz Mama Midir woreda are very traditional and inefficient. To lessen this problem, water pricing (valuation) has been considered to be a promising tool. This study, therefore, examined smallholder farmers' willingness to pay and determinants affecting their decisions to pay for improved irrigation water use in Menz Mama woreda, North Shewa zone, Amhara national regional state of Ethiopia. Cross-sectional data collected from 215 randomly sampled irrigation beneficiaries were used for analysis. The mean WTP from double bounded dichotomous elicitation method ranges from 164.027 Birr (4.17 USD) to 221.059 Birr (5.62 USD) per year per hectare of irrigable land. The result from the seemingly unrelated bivariate probit model estimation revealed that the sex of the household head, total annual farm income, size of irrigable landholdings of the household, frequency of extension contacts, amount of credit, and dissatisfaction with the existing irrigation service positively and significantly influenced farmers' WTP decisions. In contrast, off-farm income and bid values were negatively related to WTP decisions. Therefore, the aforementioned factors affecting farmers' decisions to pay should be taken into consideration when constructing irrigation schemes in the study area and areas with similar economic and socio-cultural settings.

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Willingness to pay; improved irrigation water; seemingly unrelated bivariate probit; Ethiopia

1. Introduction

The current supply of water cannot meet the ever-increasing global demand of the world population. Therefore, water has become a scarce resource (Aydogdu 2016). Such scarcity of water resources leads to over-competition and conflicts among users, and this call for interventions towards efficient allocation. Thus, it is essential to make decisions about the conservation and allocation of water resources in line with social objectives such as economic efficiency, sustainability, and equity. Water pricing (valuation) is a promising tool for efficient water utilisation and prioritisation among other uses (Chandrasekaran, Devarajulu, and Kuppannan 2009; Latinopoulos 2005).

Currently, Ethiopia is characterised by rapid population growth, which increases the demand for water (for irrigation and drinking). Thus, efficient utilisation of this resource is pertinent to increasing the production and productivity of smallholder farmers and to meeting the rising demand for food. In this regard, irrigation plays a vital role by enhancing smallholder farmers' productivity and fulfilling their growing demand for food (Mosissa and Bezabih 2017). Moreover, irrigation development is decisive in enhancing smallholder's livelihood through crop production, increasing crop variety, improving productivity, and lengthening agricultural seasons (Eshete, Sinshaw, and Legese 2020).

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Hence, access to improved irrigation water has a significant contribution to poverty reduction and enables smallholder farmers to improve their well-being.

However, smallholder farmers in Ethiopia do not have access to suitable irrigation infrastructure and affordable irrigation technologies. Rather, they depend on unproductive and traditional irrigation techniques (Mosissa and Bezabih 2017). This problem coupled with frequent drought exacerbates the prevalence of food insecurity and hunger. To this end, the government has given priority to irrigation development by focusing mainly on the establishment and improvement of small-scale irrigation schemes.

The water use practices in the Menz *Mama Midir woreda*, particularly along the *Zol and Waka* rivers are no different from other areas of the country. Farmers along the river basins command irrigation water from the rivers to their farmland through traditional methods[1] such as river diversion and irrigation through canals and plastic pipes, all of which cause water wastage. As a result, farmers have not benefited from the enormous potential benefits due to the lack of a well-constructed irrigation scheme and regulation to use the resource.

To solve the aforementioned irrigation-water use problem and improve the livelihood of farmers, the government is working aggressively on the construction of modern small-scale irrigation schemes, in different areas of the country (Dawit, Dinka, and Leta 2020; Kassie 2020; Getnet et al., 2022). However, such improvement in irrigation schemes cannot be attained freely; rather, it requires a huge investment (Embaye et al. 2020; Gebregziabher et al. 2013). Thus, such investment in modernizing the traditional irrigation scheme might not be easy for the district. Hence, the involvement and cooperation of the local community is important for the success of the irrigation scheme. Therefore the execution of a modern irrigation system requires the willingness of the local community to assist the cost of operation, maintenance, and management. For this reason, the estimation of farmers' willingness to pay (co-financing) for improved irrigation water use is of utmost importance for its sustainable use.

Therefore, this study was initiated to estimate smallholder farmers' willingness to pay for improved irrigation water use and to identify the determinants that could affect their payment decisions based on the following research questions: (1) How much is the mean WTP of smallholder farmers' for improved irrigation water provision in *Menz Mama Midir woreda?* (2) What are the factors that determine smallholder farmers' willingness to pay for improved irrigation water use in *Menz Mama Midir woreda?* These research questions are not addressed by current academic literatures, particularly in Menz Mama Midir woreda.

To the best of our knowledge, this study is the first of its kind, particularly for the study area, and as such it will fill the gap in the literature. The study could offer important information for authorities, policy-makers, and other stakeholders to design appropriate irrigation water use strategies and implement investment decisions (construct if the value households attached to the improved scheme is greater than construction costs). Knowledge of the factors that affect farmers' WTP could also help in revising the existing water resource use strategies. Furthermore, researchers who would be interested in conducting research in the study area on improved irrigation water use and related topics could take it as baseline information.

2. Methodology

2.1 Description of the study area

Menz Mama Midir is a district in the Amhara regional state of Ethiopia, located at the eastern edge of the Ethiopian highlands in the northern Shewa zone. It is located 255 km from the capital city, Addis Ababa, and 110 km from the zonal city, Debrebirhan. *Menz Mama Midir* is bordered to the south by *Mojana Wadara*, to the west by *Menz Lalo Midir*, to the north by *Menz Gera Midir,* to the northeast by *Efratana Gidim*, to the east by *Kewet,* and the southeast by *Tarmaber.* The administrative centre of this woreda is *Molale*.

The district has 19 rural kebeles and one urban kebele[2] administration. According to the District Agricultural Bureau, the total population is estimated at 98,422, of whom 49,013 are male and 49,409 are female. Approximately 86,972 (88.37%) of the total population are rural residents. There are 3949 irrigation water users and smallholder farmers in the woreda (MMMWAO, 2020). Of the total area of the district, which is 65,042 hectares; 42.8% is arable; 20.2% is grazing land; 13.8% is covered by forest, and the remaining 23.2% is bare land. The topography of the district was characterised as plain (46%), mountainous (27.7%), rugged (13.3%), and gorged (12.3%). The altitude at which the woreda is located ranges from 1590 m to 3414 m above sea level (MMMWAO, 2020).

2.2 Sample size determination and sampling procedures

A simplified formula provided by (Yamane 1967) was used to determine the sample size.

$$n = \frac{N}{1 + N(e)^2}, \tag{1}$$

where n is the sample size, N is the population size (total irrigation water user households found in the district), and 'e' is the precision level. The required sample size was calculated as follows:

$$n = \frac{3949}{1 + 3949(0.065)^2} = 224. \tag{2}$$

The formula was selected for simplicity once the population number was known. The precision level is set at 6.5% as the population in the study area is almost homogenous in many settings, such as cultural, socio-economic, institutional, and livelihood strategies.

A two-stage sampling technique was used for the sampling. In the first stage, three kebeles, *Angewa, Dasa,* and *Zeram* were purposively selected based on their proximity to the water sources and the availability of a relatively higher number of irrigation water users. Then, 224 irrigation water user households were selected through a simple random sampling technique from each sample *Kebeles* using probability proportionate to size. These households were taken from the sampling frame, which is the list of irrigation users (beneficiaries) for respective kebeles, which were obtained from the district agricultural and rural development office. Therefore, 36.60%, 35.27%, and 28.13% of the total samples were drawn from *Angewa, Dassa,* and *Zeram Kebeles*, respectively.

2.3 Types of data, sources of data, and methods of data collection

Primary data were collected through farm household surveys, focus group discussions, and interviews with key informants. As recommended by Arrow et al. (1993) a household survey was conducted using structured questionnaires through face-to-face interviews. Three focus group discussions, with six participants each, were held to discuss the existing irrigation practices, related problems, and possible alternatives to solve the problem. Model farmers drawn from the total model farmers whose lists were found in the Woreda agricultural office were participants in the focus group discussions. In addition, important information was obtained from key informants (district irrigation water management officers, development agents in the respective kebeles, and kebele administrators).

2.4 The stated preference methods: an overview

Stated preference methods use survey techniques to elicit willingness to pay either for a marginal improvement or for avoiding a marginal loss (Tietenberg and Lewis 2003). The prominent and commonly used stated preferences methods are the choice experiment (CE), sometimes called choice modelling, and the contingent valuation method (CVM) (Bostan et al. 2020; Johnston et al. 2017). The distinction lies in the exposition of attributes associated with the good in question. In CE it is assumed that individuals can differentiate between the attributes of the good or programme in question and assign a certain value to the change in attributes. On contrary in CVM, the good service or project in question is seen as a whole so that the valuation question is also appropriately set up to measure the good or programme as a whole (Johnston et al. 2017).

CVM is preferred to the choice experiment in that it is analytically much simpler, suitable to produce a single valuation estimate for a programme of interest and it needs low cognitive capacity for valuing particularly complicated goods (choice experiment entails that goods be broken down into its attributes and that levels be assigned to each of these attributes; this is often quite difficult and respondents could also face a difficulty to reveal their preference) (Bostan et al. 2020). Therefore, this study employed the CVM, owing to its flexibility and ease of implementation.

The contingent valuation method (CVM) is one of the stated preference techniques in which a hypothetical market scenario is developed and described to the survey respondents so that they are asked directly to reveal their willingness to pay (WTP) for a non-marketed good under a given condition or a prescribed circumstance (Mitchell and Carson 1989). The method is thus “contingent” in the sense that WTP is asked contingent on certain hypothetical scenarios. It is an extensively used non-market valuation method (Ready, Buzby, and Hu 1996).

Moreover, contingent valuation evolved as a method to estimate the benefits of non-marketed environmental goods and services so that the benefit could be incorporated into cost–benefit analysis, which is a pillar for optimal allocation of resources (Bateman and Willis 2000). It has ease of flexibility and hence, an acceptable method for estimating the benefits produced by water resource projects including non-use (passive-use) values (Carson, Flores, and Meade 2001; Young 2005).

Although CVM has been extensively used by many researchers for natural and environmental resource valuation, the method has some inherent biases that affect the validity and reliability of the results (Arrow et al. 1993). The common and foremost biases in contingent valuation (CV) surveys are starting point bias, strategic bias, hypothetical bias, and interviewer bias (Tietenberg and Lewis 2003). Such biases may arise from the hypothetical nature of the market, the way the good is described, the elicitation format used, and the payment vehicle by which respondents express their WTP (Carson 2000). Therefore, this study tried to minimise the biases through a well-designed questionnaire and thoroughly implementing it in the field, and by employing an incentive compatible[3] elicitation method (i.e., the double-bounded dichotomous choice).

2.5 Elicitation method used, and initial bid sets

The elicitation questions in the CVM method take numerous formats: The most widely used elicitation formats are open-ended, bidding game, payment card, and dichotomous choice (Hanley, Mourato, and Wright 2001). However, the National Oceanic and Atmospheric Administration (NOAA) panel recommends practitioners use the dichotomous choice method (Arrow et al. 1993). Hanemann et al. (2013) analytically showed that the extra information gained from the follow-up question makes the double-bounded dichotomous choice (DBDC) format estimates more efficient than the single-bounded dichotomous choice (SBDC) estimates, and they asserted that the efficiency gain from the DBDC format was quite large. The yes-no and no-yes responses in the double-bound dichotomous choice make clear bounds on the unobservable true WTP, which is not possible in the single-bounded choice question (Haab and McConnell 2002). As a result, this study used the DBDC question format to elicit farmers’ WTP in the study area to pinpoint the true WTP. In addition, as suggested by (Ahmed and Gotoh 2014) an open-ended elicitation question following the DBDC questions was asked to identify whether there was inconsistency in response to the second response of the DBDC elicitation question and the maximum willingness to pay they stated.

Initial bids for the DBDC questions were identified through a preliminary survey. In the field survey, farm households were asked to express their maximum willingness to pay they would be willing to pay if the intervention is made true. From the ranges of bids stated by respondents, the three most frequent bids were chosen as an initial bid for the final survey. These bids were 120, 150, and 200 Ethiopian Birr per timad[4] (0.25 ha) of irrigable land per annum.

The choice of payment vehicle is an important issue in the CVM study. It should satisfy conditions such as credibility, familiarity, feasibility, and universality (Mitchell and Carson 1989). The vehicle has to be credible in representing a realistic situation and households also have to be familiar with it. It also should be feasible in the sense that it shows the capability of the recipient of funds in delivering the improvement and be universal in that it should affect all respondents or households equally important. This study has used monetary payment in the form of irrigation water fees as a payment vehicle since it satisfies the above conditions. Additionally, the enforceability and thereby incentive incompatibility of the monetary payment vehicle was considered while choosing the appropriate payment mechanism. The focus group discussants and key informants also approved the monetary payment in the form of an annual irrigation water fee for its incentive incompatibility and plausibility.

2.6 Econometric model specification

The type of elicitation method employed determines the econometric model used. This study used a double-bound dichotomous choice with open-ended follow-up questions. Two Binary data points can be obtained from this question format: one from the first question and another from the follow-up question. In the contingent valuation study with follow-up questions, the assumption that respondents refer to the same underlying WTP value in answering the first and follow-up questions is considered questionable in many applications as the response to the follow-up question is often not independent of the first response (Konishi and Adachi 2011). Econometrically, this non-independence between the two valuation functions for responses one and two may be accommodated by explicitly accounting for cross-equation correlation in the estimation process, and this can be accomplished by assuming a bivariate normal distribution of the error term (Poe, Welsh, and Champ 1997). Hence, the bivariate normal density function is appealing because it allows for nonzero correlation, whereas the logistic distribution does not (Cameron and Quiggin 1994). As such, this study employed the bivariate probit model, which is a natural extension of the probit model that involves more than one equation with correlated error terms (Greene 2012).

However, in exceptional cases where the correlation coefficient between the error terms of the first and the second response equations is zero, the two responses are independent, and if the correlation is 1, the two responses are primarily the same. In both cases, the bivariate probit specification is not appropriate. For brevity, independent probit and interval data models should be used in cases where the correlation coefficient (rho) is zero and one, respectively.

Following (Haab and McConnell 2002), the four possible responses in the double-bounded dichotomous choice elicitation method with their probabilities are as follows:

$$t^1 \leq \mathbf{WTP} < t^2\text{: } \mathbf{Pr}(\boldsymbol{yes}, \boldsymbol{No}) = \mathbf{Pr}(\mu_1 + \varepsilon_{1j} \geq t^1, \mu_2 + \varepsilon_{2j} < t^2), \tag{3}$$

$$t^1 > \mathbf{WTP} \geq t^2\text{: } \mathbf{Pr}(\boldsymbol{no}, \boldsymbol{yes}) = \mathbf{Pr}(\mu_1 + \varepsilon_{1j} < t^1, \mu_2 + \varepsilon_{2j} \geq t^2), \tag{4}$$

$$\text{WTP} \geq t^2\text{: } \mathbf{Pr}(\boldsymbol{Yes}, \boldsymbol{Yes}) = \mathbf{Pr}(\mu_1 + \varepsilon_{1j} > t^1, \mu_2 + \varepsilon_{2j} \geq t^2), \tag{5}$$

$$\text{WTP} < t^1\text{: } \mathbf{Pr}(\boldsymbol{No}, \boldsymbol{No}) = \mathbf{Pr}(\mu_1 + \varepsilon_{1j} < t^1, \mu_2 + \varepsilon_{2j} < t^2), \tag{6}$$

where t^1 and t^2 are the first and second bid values, respectively.

Following (Cameron and Quiggin 1994), the econometric model for the formulation of double-bounded data is given as follows:

$$\text{WTP}_{ij} = \mu_{ij} + \varepsilon_{ij}, \tag{7}$$

where WTP_{ij} represents the j^{th} respondent's willingness to pay, $i = 1, 2$ represents the first and second answers, μ_1 and μ_2 are the mean values for the first and second responses, respectively, and ε_{ij} represents the unobserved random component. Setting $\mu_{ij} = X_{ij}\,\beta_i$ allows the mean to depend on respondent characteristics.

In the seemingly unrelated bivariate probit regression model, the dependent variable represents respondents' responses to the initial and follow-up bid values. These are binary variables that take the value 1 if the respondent accepts the proposed value and 0 otherwise. According to Greene (2002), the general specification of the seemingly unrelated bivariate probit model can be formulated as follows:

$$WTP_1^* = \alpha_1 + \beta_1 t_1 + \sum_{i=1}^{n} \beta_i X_i + \varepsilon_1, \tag{8}$$

$$WTP_2^* = \alpha_2 + \beta_2 t_2 + \sum_{j=1}^{m} \beta_j X_j + \varepsilon_2, \tag{9}$$

$$\text{Cov}\,(\varepsilon_1, \varepsilon_2) = \rho,$$

where WTP_1^* and WTP_2^* are the j^{th} farmer latent WTP when s/he responds to the initial and subsequent WTP questions, respectively; t^1 and t^2 are the initial and second bids, respectively; α's and β's are parameters to be estimated; ε_1 and ε_2 are error terms normally distributed with mean zero and respective variances σ1 and, σ2 and have a bivariate normal distribution with correlation coefficient ρ. Where $\rho \neq 0$; X_i refers to the independent variables. The independent variables other than the bid variable are the same in the two equations above (i.e., $X_i = X_j$).

The mean willingness to pay was determined following (Haab and McConnell 2002).

$$MWTP = -\frac{\boldsymbol{\alpha}}{\boldsymbol{\beta}}, \tag{10}$$

where MWTP is the mean WTP for improved irrigation water use, α is the intercept of the model, and β is the coefficient of bid values offered to respondents (i.e., β_1 and β_2). Meanwhile, Lopez-Feldman (2012) has developed a command called *doubleb* to directly estimate the mean WTP using maximum likelihood from a double-bound dichotomous contingent valuation survey.

2.7 Calculating aggregate willingness to pay

The value of public goods is the sum of the values of individual agents who can enjoy them (Samuelson 2007). Individuals manage the amount of consumption of marketed goods given their prices. However, individuals face the same level (similar services) of public goods; what varies is their (individual's) level of utility. Each individual's utility can be measured by WTP for the public good. Therefore, the total value society attaches to the public good (i.e., social welfare) is obtained by the aggregation of individual welfare. Therefore, it is reasonable to calculate the welfare of each individual in the sample and then use the sample mean for aggregation. However, the aggregate value is dependent on how protest responses[5] are utilised in the analysis (Desvousges, Smith, and Fisher 1987).

Despite there are three ways of dealing with protest zero bids: (1) drop them from the data set; (2) treat the protest bids as legitimate zero bids and include them in the data set; or (3) assign protest bidders mean WTP values based upon their sociodemographic characteristics relative to the rest of the sample group, they are usually dropped from the analysis (Halstead, Luloff, and Stevens 1989). The inclusion of protest zero bidder's results in underestimating the mean WTP and, thereby the aggregate benefits (Halstead, Luloff, and Stevens 1992). Hence, following studies by (Belay, Ketema, and Hasen 2020; Erkie, Bekele, and Fentaw 2022; Saleamlak & Alem, 2018; Tesfaye, Balana, and Bizimana 2021), the present study excluded protest zero bids from aggregate willingness calculation. Moreover, the fact that the overall survey response was 100% and the number of protest responses was very small (about 4%), the deletion of protests could not cause sample selection bias.

3. Results and discussion

3.1 The contingent valuation survey results

3.1.1 Distribution of responses for the DB-DC

Three sets of bids determined through a preliminary survey were randomly and evenly distributed to the sampled respondents. As can be seen from Table 1, of the total 215 respondents, 30.7% responded affirmatively for both the initial and follow-up bids; 27.91% refused both bids offered; 23.72% accepted the initial bids posed and refused the follow-up bids, 17.67% refused the first offered bids and accepted the second offered bids.

3.1.2 Reasons for maximum willingness to pay and unwilling to pay

Respondents were asked open-ended questions about their maximum willingness to pay following double-bounded dichotomous questions. Their maximum willingness to pay ranged from 0 to 500 Birr per *timad* (0.25 ha) of irrigable land per year. Following the open-ended question, they were also asked a debriefing question about their reason for maximum willingness to pay or unwillingness to pay. Among the total valid respondents, 83.72% stated a positive value, whereas the rest stated a zero value (Table 2).

Those who stated zero values as their maximum willingness to pay were asked to reveal their reason for not being willing to pay. Based on their responses, they were categorised as protestors or legitimate responses (Table 3). Categorisation was performed according to the guidelines provided by the NOAA (Arrow et al. 1993). To illustrate at this point, legitimate zero responses corresponded to respondents who had a low level of income and were not able to pay. Other responses were considered as protest zero responses because respondents stated zero as their WTP, not because they had no value for improved irrigation water. Accordingly, out of the 44 unwilling respondents who stated their reason for unwillingness to pay, 79.54% were genuine responses and 20.45% were protestors.

3.2 Econometric analysis

3.2.1 Estimation of the mean willingness to pay

The mean willingness to pay for improved irrigation was estimated to be 192.543 Birr[6] (4.89 USD) per timad per year (see Table 4). This is 1.34% of the average farm income of the farmers (Appendix 2).

3.2.2 Determinants of willingness to pay

A seemingly unrelated bivariate probit model (SUBP) was employed to determine variables influencing the likelihood of households' WTP for improved irrigation water use in the study area (Table 5). The Wald chi-square statistic was used to test model fitness. The test statistics turned out to be significant at the 1% level of significance, indicating that the model fits the data very well.

Sex of the household head (*SEX*): This variable was found to have a positive and statistically significant effect on households' WTP. This suggests that male households are more likely to pay the bids offered than their female counterparts. The marginal effect result shows male male-headed households are 32.9% more likely willing to pay for improved irrigation water provision keeping other

Table 1. Distribution of responses to the bid offered.

	Yes–Yes		Yes–No		No–Yes		No–No		Total	
Bid set; bid (Second bids)	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
120 (240,60)	40	57.14	14	20	10	14.29	6	8.57	70	100
150 (300,75)	18	24.32	18	24.32	14	18.92	24	32.43	74	100
200 (400,100)	8	11.27	19	26.76	14	19.72	30	42.25	71	100
Total	66	30.70	51	23.72	38	17.67	60	27.91	215	100

Table 2. Reasons for maximum willingness to pay.

Reasons	Percentage
I need the intervention	56.67
I could not afford more	17.22
It's a reasonable amount	26.11
Total	100

Source: Survey result, 2020.

Table 3. Reasons for unwilling to pay.

Reasons	Frequency (%)	Protest/legitimate
I do not have the financial capability to pay	27 (61.36)	Legitimate
I am satisfied with the existing irrigation service	8 (18.18)	Legitimate
I don't trust that the government will act as promised	5 (11.36)	Protest
It is the responsibility of the government to provide	3 (6.82)	Protest
Irrigation water should be provided free of charge	1 (2.27)	Protest
Total non-willing respondents	44 (100)	———-
Total protest respondents	9 (20.45)	———-
Total legitimate non-willing respondents	35 (79.54)	———–

Source: Own survey result, 2020.

variables at their mean value. This finding is consistent with those of earlier studies by Abreha and Romstad (2020) and Wassihun et al. (2021).

Total annual farm income (lnFARMINC): As expected, this variable was found to have a positive and significant effect on households' WTP. The result suggests that households with a higher income were more likely to pay an offered bid than those with a lower income. This makes intuitive sense as it conforms to economic theory, which states that demand for normal goods increases with income. The marginal effect also shows that by holding other variables constant at their mean value, a unit increase in the household's total annual farm income increases the probability of accepting the bid offered by 34.0%. Studies by Mu et al. (2019) and (Knapp et al. 2018) also find a positive association between income and willingness to pay.

Off-farm income (*lnOFFINC*): It appeared to have a statistically significant negative effect on households' WTP decisions. Households with higher off-farm income are expected to pay less attention to irrigation agriculture and are less likely to be willing to pay for improved irrigation water. A one-birr increment in the respondent's off-farm income decreases the probability of paying for improved irrigation water use by 2.9%, keeping all other variables at their mean values. The result corroborates the findings of Mu et al. (2019) and Erkie, Bekele, and Fentaw (2022) who found a similar association between this variable and WTP.

Size of irrigable landholdings of the household (SZLAND): The size of irrigable landholdings of the household influenced WTP decisions positively and significantly. For every unit (*timad*) increment in the size of irrigable landholding, the probability of WTP increased by 22.8%, keeping all other variables at their mean values. The possible reason can be households with large irrigable land expect a greater potential benefit from improved irrigation supply either by cultivating the land or renting it out, and hence tend to pay for it. The result is in agreement with the principle of economies of scale. Studies by Tesfaye, Balana, and Bizimana (2021) and Ayana (2016) also reported similar findings.

Frequency of extension contact (*EXTCONT*): The variable positively and significantly affected households' WTP decisions. From this, it can be inferred that the more frequently the farmer contacted

Table 4. Mean willingness to pay for improved irrigation.

	Coefficient	St. Err.	Z	$P > \|Z\|$	[95% Conf. Interval]
WTP	192.543	14.549	13.230	0.000	164.027 221.059

Source: Own survey result, 2020.

Table 5. Maximum likelihood estimates of the SUBP model.

Variable	WTP1	P > Z	WTP2	P > Z	Joint marginal effect	P > Z
AGE	−0.005 (0.014)	0.743	−0.020 (0.011)	0.059	−0.005 (0.004)	0.208
SEX	1.332 (0.570)	0.019	0.922 (0.444)	0.038	0.329 (0.091)	0.000***
EDU	0.038 (0.049)	0.444	0.088 (0.044)	0.047	0.026 (0.016)	0.102
FSIZE	0.086 (0.080)	0.280	0.008 (0.074)	0.914	0.016 (0.026)	0.526
lnFARMINC	0.892 (0.307)	0.004	0.870 (0.249)	0.000	0.340 (0.092)	0.000***
lnOFFINC	−0.090 (0.032)	0.005	−0.062 (0.029)	0.037	−0.029 (0.010)	0.006***
SZLAND	0.436 (0.2830)	0.123	0.706 (0.2190)	0.001	0.228 (0.082)	0.005***
LIVEHOLD	0.050 (0.089)	0.575	−0.019 (0.064)	0.763	0.004 (0.024)	0.864
EXTCONT	0.020 (0.009)	0.023	0.017 (0.007)	0.022	0.007 (0.003)	0.008***
lnACRDT	0.068 (0.025)	0.007	0.063 (0.021)	0.003	0.025 (0.008)	0.001***
DISMARK	−0.005 (0.012)	0.696	−0.007 (0.009)	0.436	−0.002 (0.003)	0.497
DISSAT	1.718 (0.563)	0.002	1.627 (0.292)	0.000	0.439 (0.060)	0.000***
TRAIN	0.125 (0.219)	0.570	0.287 (0.190)	0.130	0.083 (0.070)	0.232
BID1	−0.008 (0.003)	0.009			−0.001 (0.001)	0.033**
BID2			−0.008 (0.001)	0.000	−0.002 (0.000)	0.000***
_cons	−10.942 (3.254)	0.001	−9.081 (2.568)	0.000		
/athrho	1.430 (0.736)	0.052				
rho	0.892					

Log pseudolikelihood = −201.60756.
Number of obs = 215.
Wald $\chi^2(28) = 262.45$, Prob > $\chi^2 = 0.0000$.
Wald test of rho = 0: $\chi^2(1) = 3.77623$, Prob > $\chi^2 = 0.0520$.

Source: Own computation from field survey data, 2020.
Note: Numbers in parenthesis are robust standard errors.
*Significance at the 10% level.
**Significance at the 5% level.
***Significance at the 1% level.

extension agents, the more likely they would accept the bid offered. Stated differently, keeping all other variables at their mean values, additional contact with extension agents increases the probability of a positive response to an offered bid by 0.7%. This is perhaps because extension services are believed to enhance farmers' awareness of irrigation and the consequences of inefficient usage of water. Thus, more aware farmers are worried about the future availability of water resources and may be optimistic about paying for irrigation water. This result agrees with the findings of Belay, Ketema, and Hasen (2020) and Erkie, Bekele, and Fentaw (2022), but is inconsistent with the findings of Kidane, Weia, and Sibhatu (2019) and Kiprop et al. (2017).

Amount of credit (*lnACRDT*): The amount of credit the household received positively affected the households' WTP decision. For a one-birr additional credit received by the household, the likelihood of responding affirmatively to an offered bid increases by 2.5%. The justification is that credit could enhance farmers' cash constraints and, hence, the tendency to pay parts of it for irrigation water. This finding concurs with previous studies by Tesfaye, Balana, and Bizimana (2021).

Dissatisfaction with the existing irrigation service (*DISSAT*): Other variables held constant at their mean values, farmers who were dissatisfied with the current irrigation service had a 43.9% higher probability of responding affirmatively to the offered bid compared to their satisfied counterparts. In addition, during the survey, farmers reported that the problem of water shortages has been increasing over the past few years. The main reason was inefficient water usage coupled with an increasing number of water users. This, in turn, has led to competition for water. Respondents further reported that they were disappointed by the situation because it would be possible to use water efficiently and equitably through better management. They also showed keen interest in making an appropriate payment for the intervention, hoping that it would solve the problem. Previous study by Asado, Adicha, and Yemiryu (2022) substantiated the positive relationship between this variable and WTP.

Bid prices (*BID1/BID2*): The estimated coefficients of both the initial and follow-up bids were negative and significantly influenced WTP decisions. This demonstrates that, as the bid price increased, farmers were less likely to accept the bid. An increase in the initial bid by one Ethiopian Birr decreases the probability of accepting the bid by 0.1%. Similarly, an increase in the second bid by one Ethiopian Birr reduces the probability of accepting that bid by 0.2%. This is in line with theoretical expectations and prior empirical works (Abreha and Romstad 2020; Wassihun et al. 2021).

3.3 Analysis of aggregate willingness to pay for the improved irrigation

The mean WTP calculated from the double-bounded dichotomous data were used for aggregation. Aggregation was carried out over the total irrigation water beneficiaries found in the district. However, the expected protest zero responses[7] were deducted in the process of aggregation. Thus, the aggregate WTP was computed by multiplying the mean WTP by the number of respondents expected to pay for the proposed programme. As shown in Table 6, the aggregate WTP was found to be 456,326.91 Birr (11,596.62 USD) per year.

4. Conclusions and policy implications

This study proved the need to construct an irrigation scheme that could solve the problems associated with traditional irrigation supply systems as majority, about 180 (83.72%), of the respondents are willing to contribute to the proposed improvement. The estimated aggregate benefit from the improvement was calculated to be 456,326.91 Birr (11,596.62 USD) per year with a mean WTP of 192.543 Birr per (39.35 USD) *timad* per year. This suggests the possibility of introducing an irrigation user fee, which in turn could recover the costs of the project and improve water use efficiency.

The study results revealed that female household heads were less likely to pay than male household heads. This could be related to their relative wealth position in the community. Female within the household have a limited bargaining power specifically in the study area as male control over almost all household's resources, including the land resource. The government need to reform the land ownership right which was dominantly owned by males. This will in turn enhance their eligibility for access to credit as credit offering institutions in the study area require a collateral. Female headed household willingness to pay could be improved provided that they own the land rights and access a better credit. Total annual farm income and the amount of credit received positively influenced irrigators' WTP decisions. Hence, interventions that could improve farmers' farm productivity and thereby their income should be in place.

Credit is believed to be a promising way to enhance agricultural productivity by reducing income constraints. Farmers can invest part of the credit received for production inputs complementary to irrigation agriculture. Consequently, they will have better returns and their tendency to pay for irrigation will increase. Therefore, government rural finance policies as institutions and relevant authorities as stakeholders should focus on enhancing the capacity of credit service providers to support a greater number of farmers, based on their loan demand. They also need to provide credit services with possible minimum collateral requirements, relaxed or improved loan repayment periods, and affordable interest rates.

Moreover, the study found that the frequency of extension contact and the household's education level affect the decision to pay for improved irrigation water use. Extension agents serve as a bridge to link farmers with government officials at different levels and non-governmental organisations. Hence,

Table 6. Aggregate willingness to pay.

Total irrigation users in the district[a]	Expected protest zero[b]	Expected valid response[c]	Mean WTP[d]	Total WTP[e]
3949	1579	2370	192.543	456,326.91

Source: Survey result, 2020.
[b]Is equal to the percentage of protest sampled households (4.0%) multiplied by the total irrigation user households (a).
[c]Is total irrigation users in the district (a) minus expected protest bidders (b).
[d]Is the estimated mean WTP.
[e]Is equal to expected valid responses (c) multiplied by Mean WTP amount (d).

extension personnel should contact farmers frequently and disseminate the necessary knowledge. They should also create awareness of the pre-existing, existing, and future potential status of water resources and need to teach farmers about the benefits of resources and the losses from their deterioration.

Farmers who were not satisfied with the current irrigation supply system were more likely to pay an irrigation water fee. The dissatisfied respondents constituted 84.65% of the respondents, indicating that the majority of the respondents understood the existing water usage problems. Policy-Researchers can target these individuals to help determine the root causes of their dissatisfaction so that they can handle them accordingly. In other words, stakeholders and irrigation development officials can design appropriate future interventions based on information obtained from dissatisfied farmers. This group of farmers is assumed to have a better understanding of the problems associated with the existing irrigation water.

Farmers who own large sizes of irrigable land were more likely willing to pay than those who own small plots of land. Therefore, there is a need to consider the size of the irrigable land that farmers hold while constructing an irrigation scheme. In addition, awareness of how to enhance the productivity of the existing land is needed by the relevant authorities. Cluster farming can perhaps be one way to enhance land productivity.

Lastly, we believe that this study follows good methodological rigour to estimate smallholder farmers' willingness to pay and identify a set of factors determining their decision to pay in *Menz Mama woreda*. However, the accurate generalizability of the results might be questionable as the study is geographically limited to the *Menz Mama woreda* only. Therefore, further research by broadening the scope is required.

Another limitation of this study is that it merely solicits the value farmers attached to the improved irrigation service that the water resources (*Zol* and *Waka* rivers) provide. It overlooked the multiple alternatives uses that the water resources render. Thus, incorporating other use values is highly recommended for future study.

Notes

1. Traditional irrigated methods are communal managed irrigation systems where by the diversion weirs are constructed with local materials and are usually washed away every year, and hence they have to be reconstructed annually. Typically earth canals are used. Like the traditional methods, modern communal irrigation schemes are managed locally but with concrete diversion weirs and sometimes concrete primary canals. Sometimes, secondary canals are also lined (Makombe et al. 2017)
2. The smallest administrative division in Ethiopia.
3. An incentive compatible mechanism is one in which the respondent theoretically has the incentive to truthfully reveal any private information asked for by the mechanism or that truthful preference revelation is the dominant strategy (Carson, Groves, and List 2014).
4. Timad is a local measure of land size, in which one timad is equivalent to 0.25 ha.
5. Protest zeros occur when respondents reject some aspect of the contingent valuation (CV) market scenario by reporting a zero value even though they place a positive value on the amenity being valued (Fonta, Ichoku, and Kabubo-mariara 2010; Havet et al. 2015).
6. Ethiopian currency (1USD = 39.35 Birr at December 31, 2020).
7. Represents the number of households expected to protest for the proposed intervention, which is obtained by multiplying the percentage of protest sampled households by the total number of irrigation beneficiary households.

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Data availability statement

Data supporting the findings will be available from the corresponding author upon request.

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Appendix A.

Table A1. Description of variables and their hypothesised relationship with willingness to pay decision.

Variable	Variable description	Type	Measurement	Hypothesis
AGE	Age of household headed	Discrete	In year	+/-
SEX	Sex of household head	Dummy	1 = Male; 0 otherwise	+
EDU	Education level of household headed	Discrete	years of schooling	+
FSIZE	Family Size	Continuous	Adult equivalent	+/-
FARMINC	Total Annual Farm Income	Continuous	Ethiopian Birr	+
OFFINC	Off-farm income	Continuous	Ethiopian Birr	+/-
SZLD	Size of irrigable landholdings of the household	Continuous	*Timad* (0.25 ha)	+
LIVEHOLD	Livestock holding	Continuous	Tropical Livestock Unit	+
EXTCONT	Frequency of extension contact	Discrete	Number of contacts	+
ACRDT	Amount of credit	Continuous	Ethiopian Birr	+
DISMARK	Distance to the nearest market	Continuous	Time taken in minutes	-
DISSAT	Dissatisfaction with the existing irrigation service	Dummy	1 = satisfied; 0 otherwise	+
TRAINING	Participation in irrigation water management training	Dummy	1 = participated; 0 otherwise	+
BID	Bid prices	Discrete	Ethiopian Birr	-

Appendix A2. Summary statistics for continuous variables.

Variables	N = 215			
	Mean	Std. Dev.	Min	Max
AGE	43.186	9	27	75
EDU	2.242	2.036	0	9
FSIZE	4.185	1.288	1.75	8.15
FARMINC	14383.535	7266.245	4000	45000
OFFINC	934.093	1025.734	0	6000
SZLD	0.774	0.452	0.25	2
LIVEHOLD	4.402	1.606	1	8.96
EXTCONT	18.735	12.367	0	52
ACRDT	3353.953	4691.113	0	18000
DISMARK	35.702	10.409	8	80

Appendix A3. Variance inflation factor for continuous variables.

Variables	VIF	1/VIF
BID2	1.418	0.705
OFFINC	1.351	0.74
AGE	1.313	0.762
LIVEHOLD	1.292	0.774
FARMINC	1.256	0.796
DISMARK	1.166	0.857
BID1	1.141	0.876
ACRDT	1.126	0.888
EXTCONT	1.123	0.89
FSIZE	1.121	0.892
EDU	1.072	0.933
SZLD	1.056	0.947
Mean VIF	1.203	.

Appendix 4.

Willingness to pay questions

Scenario Description

As you know the main sources of irrigation water in this area are the "**Zo**l" and "**Waka**" rivers. The irrigation water from the rivers is used through traditional methods such as river diversions and irrigation through canals and plastic pipes and all these cause water wastage. Besides, these traditional irrigation systems are associated with erosion, siltation, waterlogging, and soil nutrient mining problems. These problems have led to poor performance of water distribution in terms of sufficiency, sustainability, reliability, and equity. The situation even becomes worse in the dry season when the flow of the rivers decreases in large amounts and a large number of irrigators demands water for irrigation. Due to this, competition and conflict on irrigation water use remain a severe problem in this area. Therefore, the water supply situation in your area is likely to get worse and only part of irrigation water demand will be met in the future unless something is done.

One way to overcome the aforementioned problems is to improve the existing irrigation water supply system by constructing a modern irrigation scheme. Suppose that the scheme will be constructed in your community; this will bring about numerous benefits: it will help farmers to farm all year round so that it reduces their reliance on rainfall, and it will serve as erosion drainage and flood control measures during the wet season. It will also enable you to use the opportunity cost of time (you spent to bring irrigation water from a distance) and labour (to remove siltation) for another productive activity. Further, you may use the water from this scheme for livestock production and fattening. Hence, the construction of an irrigation scheme in this area is very crucial to lifting your livelihood through its multidimensional benefits.

However, any improvement to the irrigation water supply system will cost money; the costs include initial investment costs, labour costs, operation, and maintenance costs. These costs should be covered by the beneficiary households in the command area. Therefore, you will be charged a yearly irrigation water fee through irrigation user committees selected from you by yourselves. The fee will be based on the amount of hectares of land irrigated. Bear in mind that there will be no option to get the water without paying an annual fee which is essential for operation and maintenance purposes. Furthermore, we want to assure you that the proposed intervention will only be implemented if all irrigation beneficiary households contribute to the intervention and if the amount collected is sufficient to cover all costs required for the proposed programme. Now, we are going to ask you some questions to know if you would be willing to pay money to ensure that the newly constructed scheme will be successful in your community. Therefore, provide your truthful response by considering your income constraints and necessary expenses.

Did you understand everything that I was saying? (If not, then the enumerator should repeat the above sentences.)

1. Are you willing to contribute to the improved irrigation water provision if it costs your household **120/150/200** ETB per year per timad (0.25ha) of irrigable land over the next five consecutive years?
   1 = Yes   0 = No
2. **If Yes for Q1**, would you be willing to pay **240/300/400** ETB per year per timad (0.25ha) of irrigable land over the next five years?
   1 = Yes (Go to Q4)   0 = No (Go to Q4)
3. **If No to Q1**, would you be willing to pay **60/75/100** per *timad* of irrigable land per annum for a five-year horizon?
   1 = Yes (Go to Q4)   0 = No (Go to Q4)
4. Now, if you are asked the maximum amount that you would be willing and able to pay, then what is your maximum amount of WTP per year for the project to be successful?

   Amount of money in Ethiopian birr: ________________

5. Response pattern: 1 = YY   2 = YN 3 = NN   4 = NY
6. What is the main reason for your maximum willingness to pay?
   1 = I really need the intervention
   2 = I could not afford more
   3 = It's a reasonable amount
   4 = Other reason (specify)________________________________
7. **For interviewer**: If respondent indicates that he/she would not willing to pay anything for the proposed intervention, ask them the reason why they are not willing to pay?
   1 = I do not have the financial capability to pay
   2 = Irrigation water should be provided free of charge
   3 = It is the responsibility of the government to provide
   4 = I am satisfied with the existing irrigation service
   5 = I am not confident that the money collected will be used to improve the supply of irrigation water
   6 = Others, please specify_____________________________