

Determinants of farmers' willingness to pay for irrigation improvements in Northcentral Ethiopia

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ABSTRACT

Investing in agricultural water management by improving irrigation schemes helps to establish climate-resilient and sustainable agri-food systems, thus contributing to sustainable poverty reduction. The purpose of this study was to identify the determinants of farmers' willingness to pay (WTP) for irrigation water improvements in Northcentral Ethiopia. Primary data collected from a random sample of 132 households were analyzed using the double-bounded contingent valuation method and binary logit regression model to identify what determines farmers' WTP for irrigation improvement. The findings show that farmers' mean WTP for irrigation water improvements is 141.60 Birr/ha/year (2.50 USD/ha/year). The results of bivariate Probit model revealed that crop type, education, relative location to the irrigation scheme, irrigated plot size, and perceived drought risk statistically and positively determine farmers' WTP for irrigation water improvement. These findings offer valuable policy implications on how best to guide practical agricultural water management. Policy interventions aimed at enhancing farmers' behavior, awareness, and perception of drought-related issues, while also promoting cash crop production, are likely to drive more farmers towards a positive WTP for irrigation water improvement.

1. Introduction

Ethiopia is endowed with an abundant groundwater potential of approximately 2.6 billion (Berhanu et al., 2014). The contributions of irrigation to agricultural GDP and overall GDP are estimated to be approximately 9% and 3.7%, respectively (Hagosa et al., 2011). Small-holder farmers dominate Ethiopia's agricultural sector, which is characterized by a high dependence on rainfed agricultural practices (Belay et al., 2017; Chamberlin et al., 2011). Rainfall is still a key determinant of food security in Ethiopia due to the high reliance on farming and home-produced food, as well as a lack of irrigation. However, this dependence causes the country's agriculture and economy to suffer from recurring drought, food shortages, sanitation issues, and poverty (Hailu et al., 2023). Crop production by smallholder farmers may fail to constitute a viable livelihood option during variable and insufficient distributions of rainfall over crop growing periods. Furthermore, recurring droughts have resulted in low crop yields, resulting in severe hunger, malnutrition, and food scarcity. Similarly, increased weather variability and climatic change have negative impacts on the economy, and the country suffers from a food deficit. Studies show that climate change is a major emerging factor that has a negative impact on society,

the environment and the economy (Muluneh, 2021; Ngcamu and Chari, 2020; Rocha et al., 2022). Ethiopia is affected by these conditions and has also faced weather-related challenges. As a result, addressing climate change has significant implications for poverty reduction, equality, and human rights (Soergel et al., 2021).

This indicates that developing small-scale irrigation into large-scale irrigation is necessary to meet the nation's food demands, as well as the raw material demands of the growing local agro-industries. Therefore, investment interventions are needed to improve irrigation systems by establishing large-scale irrigation schemes. This is because, given the agricultural sector's high dependence on erratic rainfall and the alarming increase in climate change (Belay et al., 2017), a significant shift from predominantly rain-dependent farming systems to irrigated agriculture is considered one of the solutions to improving food security in drought-prone areas (Vanschoenwinkel and Passel, 2018). What drives smallholder farmers' willingness to pay (WTP) for agricultural water improvements is an important question for policymakers and researchers, because improved access to irrigation technologies can increase resilience to climate change, increase agricultural yield, improve food security and help enhance the economic status of farming households. Better understanding of farmer characteristics and policy

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mechanisms that determine their WTP help practitioners to guide agricultural water management practices and programs that target those most likely to be willing to pay for and benefit from it.

Although the literature on WTP for improved irrigation water supply is extensive from the perspective of established large-scale irrigation and drainage projects (Alemayehu, 2014; Assefa, 2012; Ayana et al., 2015; Girma et al., 2021; Kidane et al., 2019; Getnet et al., 2022a; Getnet et al., 2022b; Tabeer et al., 2023), very few studies have estimated farmers' WTP for improving small-scale irrigation schemes into large-scale schemes. This study will advance understanding of farmers' WTP for improved irrigation water supply and will provide insights into how best to guide agricultural water management practices and policies based on empirical evidence. Furthermore, findings will also help irrigation water pricing and development efforts in other regions or contexts with similar agricultural water challenges. Building on theoretical framework from [random utility theory](#), this study answered two research questions in the context of improving small-scale irrigation into large scale irrigation: (1) How much is farmers' average WTP for irrigation water improvements? (2) What determines farmers' WTP for irrigation water improvement?

2. Materials and methods

2.1. Study area and sampling

The study was conducted in Machakel district, *Gedeb*, a small-scale irrigation scheme located at *Yewula* kebele along Debre Markos to Bahirdar main road (see [Fig. 1](#)). Specifically, the small-scale irrigation scheme is located within *Yewula* kebele¹ but encompasses more kebeles from the upper and lower watershed areas.

To select representative sample households, a two-stage sampling procedure was used to collect primary data on their socioeconomic, institutional, and bid values. The first stage involved random selection of two watershed areas (upper and lower) with actual irrigation water user households and potential irrigation water user households for crop production, contingent on the improvement of the irrigation scheme. At the second stage, a systematic random sampling technique was used to select proportionate sample households based on the size of households within the two watershed areas. The simplified sample size determination formula developed for survey research was used to determine representative sample households at a 95% confidence level, 0.5 degree of variability, and 5% level of precision, yielding a sample size of 132 households (Adam, 2020).

2.2. Data and ethical considerations

Throughout the data collection process, participants were asked for their informed consent and informed about the confidentiality of their responses. Then, structured interview was prepared and pretested by conducting a pilot survey on few randomly selected households to allow modifications before the actual survey. The data collection procedure was accompanied by training experienced enumerators and supervision of the actual data collection. Using a structured interview, primary data on socioeconomic, behavioral, spatial, institutional, and irrigation water market variables were collected from the sample households. Secondary data was also gathered from documented reports of district agricultural office to supplement evidence on potential irrigable area and potential irrigation user households. The collected data is then classified, edited, coded, and entered into Stata 18 ([StataCorp., 2023](#)) to prepare it for data analysis and interpretation.

2.3. Methods of data analysis

2.3.1. Random utility model

This study is undertaken building on the theoretical framework of [random utility theory](#) which assumes that individuals choose a consumption bundle that maximizes their utility, considering their income constraint ([McFadden, 1974](#)). Based on this model, [Hanemann \(1984\)](#) proposed the fundamental model for analyzing [contingent valuation](#) scenarios involving dichotomous response. This model outlines how to derive WTP of the i^{th} respondent from the indirect utility function as formulated below:

$$U = u_i(Y, Q, N)_i + \varepsilon_i$$

Where U is the indirect utility function, Y is the income of the i^{th} household, Q is the provision of non-marketable goods which is provision of improved irrigation water in this case, and N is the vector of household characteristics, and other institutional determinants of irrigation improvement.

WTP of a farmer for the provision of public good is the amount of income that a farmer gives up to be better off from the status quo to an improved situation ([Haab and McConnell, 2002](#)). Farmers would respond "yes" to the required bid value for the provision of an improved irrigation water when their welfare is better off from an improved situation than the status quo.

2.3.2. Bid design for double-bounded CVM

A preliminary survey was conducted to modify the questionnaire by incorporating omitted variables and determining the starting bid for the double-bounded dichotomous question format. A focus group discussion was conducted to determine the best starting bid value, and the bid value stated most frequently by the discussants was considered the initial bid offered to the sample households. The double-bounded dichotomous choice (DBDC) contingent valuation method (CVM) has dominated past literature that has valued a public good or service ([Adam, 2020](#); [Alemayehu, 2014](#); [Aman et al., 2020](#); [Anteneh, 2015](#); [Getnet et al., 2022b](#); [Wassihun et al., 2022](#)). In this study, the double-bounded Probit model was chosen over other potential models, such as the single-bounded model and other econometric models, due to its simplicity of data use to provide more efficient and an unbiased WTP estimates ([Calia and Strazzer, 2000](#)). The structure of the four interval bounds was determined using double-bounded dichotomous choice questions ([Fig. 2](#)).

2.3.3. Estimation of the mean WTP for irrigation water improvement

Previous studies investigating [willingness to pay](#) for a public good or service used a bivariate probit model with a double-bounded dichotomous choice follow-up format ([Alemayehu, 2014](#); [Aman et al., 2020](#)). This model is used to estimate farmers' mean WTP for irrigation water improvement. The econometric model of the bivariate probit model ([Cameron and Quiggin, 1998](#)) is specified as follows:

$$\begin{aligned} Y_1 &= X_1\beta_1 + \varepsilon_1 \\ Y_2 &= X_2\beta_2 + \varepsilon_2 \end{aligned}$$

Where Y_1 , Y_2 represents unobservable WTP for first and second bid responses, X_1 , X_2 , explanatory variables, β_1 , β_2 are unknown parameters to be estimated from the first and second responses, and ε_1 , ε_2 are error terms normally distributed with mean zero and respective variances σ_1 and σ_2 . From the bivariate probit model, a regression of the dependent variable (WTP) on the constant and bid values which yields the mean WTP ([Haab and McConnell, 2002](#)):

$$MWTP = -\frac{\alpha}{\beta}$$

Where $MWTP$ = mean WTP, α = coefficient for the model's constant term and β = slope coefficient of bid values offered to respondents. Suppose that "I" is the initial bid offered for the household, "I^L" is a bid

¹ The lowest administrative unit in Ethiopia

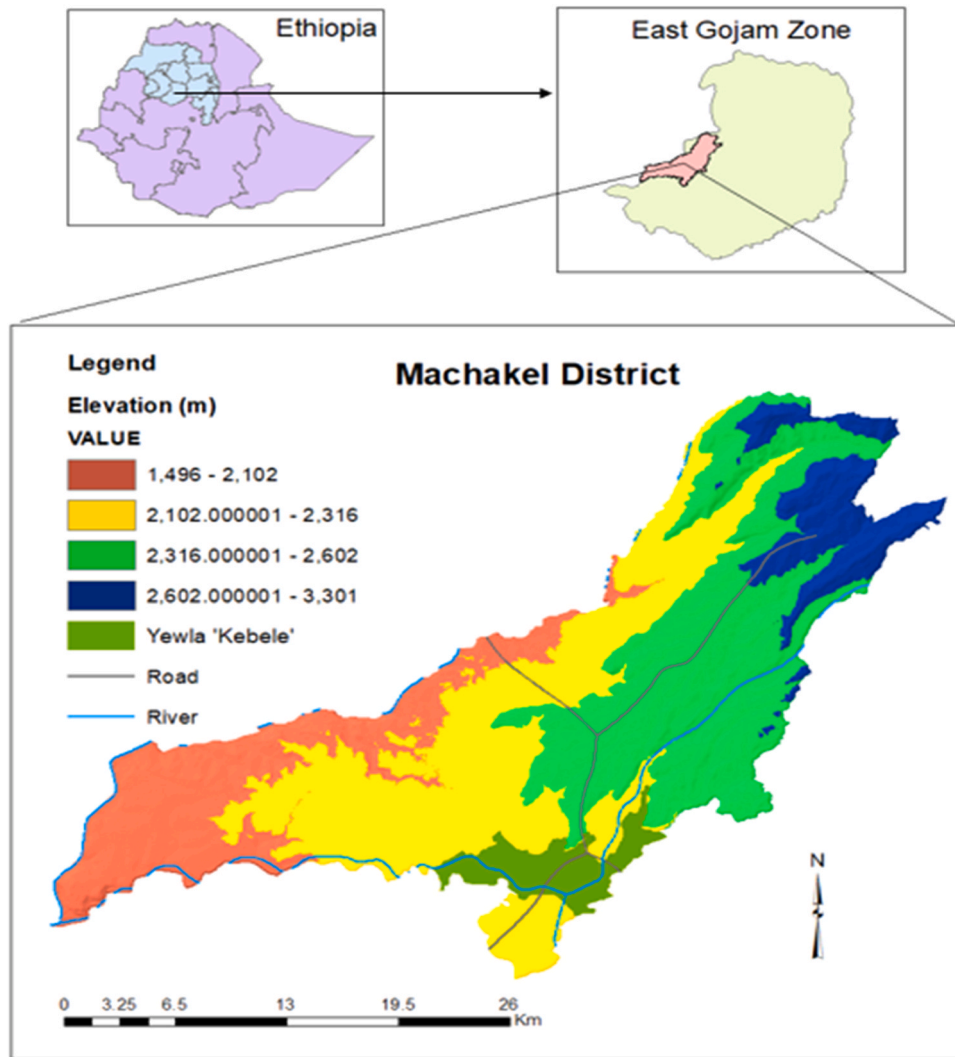


Fig. 1. Map of the study area.

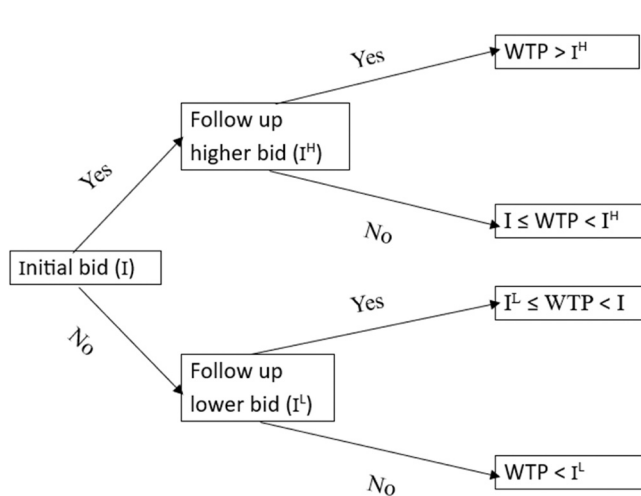


Fig. 2. Double-bounded CVM question structure for irrigation water improvement.

value lower than the initial bid offered, and " I^H " is a bid value higher than the initial bid; the interval bounds on WTP by the household are given as:

$WTP > I^H$ for yes-yes responses

$I \leq WTP < I^H$ for yes-no responses

$I^L > WTP \geq I^L$ for no-yes responses

$WTP < I^L$ for no-no responses

2.3.4. Model specification for determinants of farmers' WTP for irrigation improvement

The dependent variable, willingness to pay, is binary, taking a value of either 1 if the farmer accepts the bid or 0 otherwise, making it preferable to conduct the analysis using either the logit or probit model. Although logit and probit models produce similar parameter estimates, a binary logit regression model is the appropriate and preferred probability model recommended mostly from mathematical point of view, as it is extremely flexible for interpreting binary response dependent variables (Foster et al., 1984). Hence, binary logit model is employed to analyze the relationship between farmers' willingness to pay (WTP) for improving irrigation water and its determinants. Previous studies have similarly used binary logit model to identify what determines farmers' WTP for irrigation water improvements (Kidane et al., 2019; Abdelhafidh et al., 2022; Biswas and Venkatachalam, 2015; Tang et al., 2013). The logit regression model specified and employed in this study to identify the determinants of farmers' willingness to pay for irrigation water improvements takes the following functional form:

$$Y_i^* = \beta'X_i + \varepsilon_i$$

$$Y_i = 1 \text{ if } Y_i^* \geq b_i$$

$$Y_i = 0 \text{ if } Y_i^* < b_i$$

Where β' = represents the vector of unknown parameters of the model, X_i = vector of explanatory variables, Y_i^* = Unobservable households' actual WTP for improving irrigation water, Y_i = Discrete response of the respondents for the WTP, b_i = the offered initial bids assigned arbitrarily to the i^{th} respondent and ε_i = error term $N(0, \sigma)$.

2.4. Model variables, definition, and measurement

2.4.1. Dependent variable

The dependent variable of the model is the binary response of the household's WTP to the initial bid offered (1 = if the household is willing to accept the initial bid, 0 = otherwise). The independent variables determining household WTP and their hypothesized effect on WTP are presented in Table 1.

3. Results and discussion

3.1. Description of sample households

Nearly 46% of the respondents could read and write with average ages and family sizes of 43.4 and 4.98, respectively (Table 2). 61% of the farmers are located at the upper watershed (a proxy for the farmer's relative location in relation to the main irrigation source). 58% of all respondents maintained a positive perception regarding the likelihood of drought occurrence in the unforeseen future. 47% of households have road access, but their credit utilization remains low in comparison to their total proportion, which is only 26%. They have an average livestock holding of 5.32 TLU and an annual off-farm income of 14,360.00 Birr (253.70 USD).

Nearly 84.1% of households were willing to pay for the hypothetical

Table 1

Definition and measurement of the independent variables of binary logit model.

Variable code	Variable type	Variable definition and measurement	Expected effect on WTP
Age	Discrete	Age of the household head measured in years	+
Education level	Discrete	Education level of household head measured in years of schooling	+
Family size	Discrete	Family size of the household measured in discrete numbers	+
Cultivated land	Continuous	Household's cultivated land size in hectares	-
Irrigated plot	Continuous	Plot size under irrigation measured in hectares	+
Farmer location	Categorical	Farmer's relative location to the main irrigation source (1 = upper, 0 = lower)	-
Crop type produced	Categorical	Crop type (1: cash crops, 0: otherwise)	-
Livestock ownership	Continuous	Livestock owned by household measured in Tropical Livestock Unit (TLU)	+
Perceived drought risk	Binary	Household perceiving future drought risk (1 = yes, 0 = no)	+
Credit use	Binary	Households credit use (1 = yes, 0 = no)	+
Road access	Binary	Road access (1 = yes, 0 = no)	+
Market distance	Continuous	Distance to the nearest market measured in walking hours	-
Extension contact	Discrete	Frequency of extension contact measured in days per month	+
Bid1	Continuous	Initial bid offered measured in ^a ETB per hectare per year	-
Off-farm income	Continuous	Annual off-farm income of the household in ETB	-

^a Birr is Ethiopia's monetary unit: USD 1 = 56.6 Birr (2024).

Table 2

Descriptive statistics of the model variables.

Variables	Mean ^a	Std. Dev	Min	Max
Family Size	4.98	0.72	2.6	5.4
Education Level (1= read & write)	0.46		0	1
Age	43.4	9.26	30	54
Cultivated Land	2.10	1.43	0.25	4.00
Irrigated plot	1.02	0.46	0.012	0.75
Farmer location (1= upper)	0.61		0	1
Crop type produced (1= cash crops)	0.39		0	1
Livestock size (TLU)	5.32	2.65	0	11.87
Drought risk perception (1= yes)	0.58		0	1
Credit access (1= yes)	0.26		0	1
Road access (1= yes)	0.47		0	1
Market distance	8.51	5.24	5	12
Extension contact	1.52	0.26	0	3
Off-farm income (Birr)	14,360.00	5503.99	0	8572

^a Represents proportions of total sample households for categorical variables

improved irrigation water market proposed for improvement, while the remainder (15.9%) were not willing to pay for the intended irrigation water improvement (Table A of supplementary material). The initial bid value offered in the double-bounded dichotomous-choice question format was used to categorize participants' WTP status.

Among the 76.2% of households unwilling to participate, the majority cited lack of funds as the primary reason for their unwillingness to pay for the proposed improvement in the irrigation water project, while the remaining 23.8% were protest zeros (not willing), indicating their lack of pursuit of the project's realization for the benefit of all, partly because the government is supposed to cover all project payments (see Table B, C, and D of supplementary material).

3.2. Factors determining farmers' WTP for improved irrigation water supply

To better identify the predictors of farmers' WTP, 15 explanatory variables were included in the model to estimate the parameters of all variables using binary logit regression model. These variables were selected on the basis of previous theoretical and empirical studies. The model used household WTP (willingness to pay) as a continuous dependent variable. Six of the 15 explanatory variables included in the logit regression model demonstrated statistical significance in determining households' WTP for improved irrigation water, whereas the others did not. Education level, drought perception, irrigated plot, farmers' relative position, crop type produced, and Bid1 were highly significant (Table 3).

To assess the sensitivity of the model to changes in the number of significant covariates, two models were conducted, labeled as WTP 1 and WTP 2. Upon rerunning the model by excluding irrigated plot size, it was observed that the model remained insensitive. The likelihood ratio test statistic is equivalent to the F test in a linear regression model for measuring the goodness-of-fit of binary logit regression model. Consequently, the likelihood ratio test statistic exceeds the chi-square critical value with 15 degrees of freedom at less than the 1% significance level, supporting the null hypothesis that all slope coefficients except the intercept are simultaneously equal to zero. That is, the chi-square test value of 51.69 indicates that the model fits the data well.

Education level positively and significantly determines the probability of farmers receiving improved irrigation water at the 10% probability level. Literacy raises household awareness and proximity to new agricultural production technologies and inputs, making them eager to seek and switch to alternative production systems. This finding is consistent with previous literature on the positive influence of education on WTP for irrigation improvement (Alemayehu, 2014; Getnet et al., 2022a; Tabeer et al., 2023). A marginal analysis of education level, with other variables held constant at their mean values, reveals a 48%

Table 3
Parameter estimates of binary logit regression model.

	WTP 1	WTP 2
Family Size	-0.137 (-0.0149)	-0.154 (-0.0137)
Education (1= read & write)	1.328 (0.4790)*	1.3565 (0.4801)*
Age	1.0354 (0.3213)	1.0598 (0.337)
Cultivated land	1.652 (0.6618)	1.821 (0.6970)
Irrigated plot	1.5143 (0.0307)**	
Farmer location (1= upper)	0.387 (0.1527)**	0.3940 (0.1754)**
Crop type (1=cash crops)	0.1206 (0.0463)**	0.3106 (0.6321)**
Livestock ownership	2.0687 (0.6551)	2.0687 (0.6551)
Drought risk (1 = yes)	0.0982 (0.5408)***	0.103 (0.538)***
Credit access (1 = yes)	1.1988 (0.4281)	1.2106 (0.4311)
Road access (1 = yes)	-1.5732 (0.5619)	-1.757 (0.5207)
Market distance	-1.6724 (0.5973)	-1.8015 (0.6087)
Extension contact	0.0408 (0.0136)	0.0573 (0.0117)
Off-farm income	-4.4688 (-0.7320)	-4.4931 (-0.728)
Bid1	-0.0845 (-0.0281)***	-0.1005 (-0.0211)***
Constant	-0.2293	-0.2453
Observations	132	132
Log-likelihood	-45.62	-49.46
LRChi2	51.69	47.83
Pseudo R ²	0.357	0.306

* p<0.1

** p<0.05

*** p<0.01,

increase in the probability of a household being willing to pay for irrigation water projects for each additional year of education promoted, validating the importance of promoting adult education in rural areas.

The crop type produced was also significantly related to the probability of WTP for improved irrigation at the 5% probability level. Those involved in diversifying crop types, such as cash and tuber crops, have a greater willingness to pay. The reason for this difference is that diversifying crop production increases annual farm income, which in turn stimulates the demand for irrigated farming is an alternative method of production, rather than solely relying on rainfall. The finding is consistent with previous study that farmers are more willing to pay for irrigation programs with strong public preference for producing cash crops (Zewdie et al., 2023). Furthermore, because some crops require more moisture than others do, farm households are eager to obtain irrigation water. As a result, the marginal effect of crop type shows that whenever households diversify their crop production, their willingness to pay for the newly proposed irrigation project increases by more than 4.6%.

Perception of drought risk occurrence positively and significantly determined households' WTP for improved irrigation at the 1% significance level. In comparison to those who are not aware of drought risk, households that are increasingly aware of (perceived) drought incidence and uncertain rainfall patterns in the future are more likely to look for other sources of water to sustain their livelihoods, whether crop or livestock production. This finding is in conformity with previous finding that behavioral variables like attitude and perception are substantially influencing WTP (Tabeer et al., 2023). The marginal analysis results for drought perception indicate that, on average, when people become

aware of future drought risks, their willingness to pay increases by more than 54% compared with that of people who are not aware of future drought risks.

The initial bid is negatively and significantly related to the likelihood of farmers receiving the hypothetical irrigation water supply being willing to purchase water. The implication is that as the value of the initial bid increases, so does the likelihood of a household saying "yes" to the bid value offered. This finding is consistent with previous studies (Alemayehu, 2014; Kidane et al., 2019) and with classical economic theory of demand, which states that as the price of a good or service increases, so does the quantity demanded (maximum willingness to pay). The marginal effect of Bid1 indicates that increasing the initial bid by 10 Birr (0.18 USD) reduces the probability of willingness to pay by 28%.

Farmer location is significantly determined the likelihood of WTP for irrigation improvements at the 5% level. People in upper watershed areas demonstrated greater willingness to pay than those in the lower areas. This justifies that the likelihood of being willing to pay for improvement declines if the irrigation site is not accompanied by physical infrastructures, such as road access or market access. Closely related to this, few studies support the positive influence of suitable land topography for irrigation (Daru et al., 2023) and the negative influence of distance from the main irrigation area for WTP (Tabeer et al., 2023). Households in upper catchment showed a 15.3% increase in willingness to pay for irrigation improvement compared to lower watershed households due to their relative location.

3.3. Farmers' mean WTP for improved irrigation water supply

Prior to estimating the mean WTP for improved irrigation water services, an initial bid must be set using the mechanics of four-person focus group discussions. The most frequently stated bid value by focus group discussants was taken as an initial bid per 0.25 ha of land per year. The mean WTP for improved irrigation water using a double-bounded dichotomous choice format is shown in Table 4. The results demonstrate that the coefficients of the initial bid (first bid) and follow-up bid (second bid) are negative and significant at the 1% and 5% probability levels, respectively. This negative relationship suggests that further reduction in the initial and second irrigation water market prices tend to increase households' willingness to pay.

Furthermore, rho (ρ) was significant and positive, indicating that the two bid responses had a positive relationship. The mean WTP for the proposed irrigation water source is estimated to be 27.35 Birr/hectare/year based on the double-bounded dichotomous question format and coefficient estimates of the seemingly bivariate probit model.

3.4. Aggregate welfare benefits of improving irrigation water supply

The economic value of natural resources such as irrigation is defined

Table 4
Parameter estimates of the bivariate probit model.

Variable	Coeff	Std. Err	Z value
BID1 (Initial Bid)	-0.030**	0.016	-1.907
Constant	1.268***	0.291	4.354
BID2 (Second Bid)	-0.019**	0.009	-2.060
Constant	0.538*	0.375	1.435
Rho**	0.486	0.215	2.26
Log-likelihood		-186.12	
Number of Observations		132	
Wald chi2 (2)		19.65	
Prob > chi2		0.000	

Likelihood-ratio test of rho = 0: chi2 (1) =26.357 Prob > chi2 = 0.001

* p<0.1

** p<0.05

*** p<0.01

in terms of human welfare (Agudelo, 2001; Krieger, 2001). This implies that the value of environmental resources is determined by their effect on human welfare. Changes in the prices of private inputs and goods in the market, as well as changes in the quantities of non-marketed environmental goods, such as irrigation water, can have an impact on individuals' welfare. This change in welfare can be measured using the ordinary consumer surplus, which holds the income constant but not the utility level constant.

According to the Hicksian demand curve, welfare changes can be measured by compensating for surplus, compensating variation, equivalent variation, and equivalent surplus. By keeping the utility constant at the start, compensating for the variation and surplus calculate the gains and losses from environmental goods and services. Equivalent variation and equivalent surplus, on the other hand, measure welfare change while keeping utility constant at a specified alternative level. These four welfare measures involve payments or compensation to maintain utility at a certain level. If the proposed change increases welfare through changes in the quantity of environmental goods (improved irrigation water), compensating surplus is the appropriate welfare measure. This metric can be interpreted as the consumer's WTP to increase the additional quantity while maintaining the initial utility level.

Several factors must be considered when aggregating welfare gains using WTP measurements from any establishment or improvement of a public good that has only private benefits (Mekonnen, 2000). Aggregated welfare gain is important for decision-making in irrigation water management, realization decisions for project improvement, and future cost recovery implications during service delivery. There are four biases caused by the sample design execution that result in incorrect benefit aggregation. The following biases were detected: population choice bias, sampling frame bias, sample non-response bias, and sample selection bias. Because the random sampling method was combined with a structured interview method for the sample households, the study was free of such biases. During the estimation and analysis of the aggregate benefit, protest zero responses were excluded while extrapolating the possible protest zeros for the total population. The aggregate welfare benefit from the new irrigation water project is estimated to be 624, 031.2 Birr/ha/year (11,025.28 USD/ha/year) (Table C of [supplementary material](#)).

4. Conclusion

The findings reveal the willingness of a significant majority of households to finance agricultural water improvements and management. The mean willingness to pay (WTP) and aggregated welfare benefits indicate promising economic returns, suggesting the viability and potential of agricultural water improvements to enhance socio-economic well-being in the region. These findings offer valuable insights for policymakers and stakeholders, emphasizing the practical importance of community involvement in future agricultural water development initiatives. Findings also reveal that irrigation water pricing, crop type, education level, and perception of drought risk are statistically and practically significant factors shaping farmers' willingness to pay for irrigation water improvements.

This informs policymakers to design and implement sustainable irrigation projects by setting optimal water pricing strategies, encouraging cash crop production, and empowering farmers through education and awareness. Findings of this study will contribute to advance research in the field of agricultural water management and has implications of guiding agricultural water management practices and policies based on evidence. This research has limitations in that it didn't address consumers' WTP for drinking water improvements, and the differential impacts of different irrigation technologies on farmers' livelihoods. Therefore, future research could focus on understanding the long-term effects of improving irrigation on farmers' livelihoods, and upstream irrigation water provider farmers' willingness to accept (WTA) for improvement of irrigation water in order to design initiatives for

sustainable agricultural water management.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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CRediT authorship contribution statement

Tsegaye Molla Enyew: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.agwat.2024.108841](https://doi.org/10.1016/j.agwat.2024.108841).

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