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Research Article

Estimating Smallholder Farmers' Willingness to Pay for Sustainable Irrigation Water Use in North Western Ethiopia: A Contingent Valuation Method Study in *Gumara* Irrigation Project

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Ethiopia is the water tower of sub-Saharan Africa countries with 12 major river basins and 22 natural and artificial lakes, which make a median of 1,557.5 m^3 of water available per person per year. This study specifically was aimed to estimate smallholder farmers' willingness to pay for sustainable irrigation water use in northwestern Ethiopia using double-bounded dichotomous choice with a follow-up of open-ended contingent valuation questions. For this study, as a source of quantitative data, a total of 288 households were selected through a systematic random sampling method. Additionally, qualitative and secondary data were collected from the focus group discussions and desk reviews, respectively. A seemingly unrelated bivariate probit model and descriptive statistics were used to estimate households' mean and aggregate willingness to pay. The result of the study revealed that about 283 (98.26%) households were willing to pay for sustainable irrigation water use via constructing water storage, allocation, and distribution channels. Moreover, the result from seemingly unrelated bivariate probit model regression results from double-bounded dichotomous choice questions, mean, and aggregate willingness to pay were 950.7 ETB (€25.7) and 1,087,159.09 ETB (€29,382.7) per month and per year, respectively. On the other hand, the mean and aggregate willingness to pay from the open-ended questions were 926.059 ETB (€25.03) and 1,072,990.52 ETB (€28,999.74) per month and year per household, respectively. Therefore, the study suggested for the concerned body to introduce proper irrigation water pricing systems based on households' willingness and ability to pay. And an estimate of willingness to pay provides an indication of the demand for introducing proper irrigation water use system leading to sustainable use system.

1. Introduction

Water is a precious and crucial resource that is used for sustainable development and poverty reduction programs playing an important role in the agricultural sector, where it is used for irrigation. When water is used effectively and safely, its productivity in irrigation-based agricultural and nonagricultural production would be optimum [1].

This limits the potential for expanding irrigated areas, and for sustainable intensification and compromises the flexibility of the smallholder farmers to increased demand for food, which will trigger the distribution of water over space and time [2]. Therefore, the longer term the water supply reliability and quality are influenced by the societies' agricultural activity of using, financing, and their habit of sustainable management of water sources [3]. This implies that one of the multiple aspects affecting water usage efficiency will be the activity of water users, which will directly or indirectly impact the degree of well-being, as well as the cost of irrigation systems, which must be evaluated and contrasted from the perspectives of target users. This means one among the numerous factors of water use efficiency is going to be on water users' activity, which directly or indirectly affects the level of welfare and also the cost of irrigation systems needs to be evaluated and compared from the angle of target users [3, 4].

Globally, population growth is predicted to accelerate, necessitating increased irrigation as a means of maximizing the return from the limited land available to boost agricultural output. [5]. Irrigation is a technology with different characteristics, and this requires that irrigation is one in every measure required to bring about sustainable food production in the face of changing climatic conditions such as drought [6]. Despite irrigation having this much of importance, its development in Africa is the lowest since the supply of surface water varies tremendously [4]. Moreover, the cases in Ethiopia are blessed with abundant water resources usually referred to as "the water tower of Africa" with 12 major river basins and 22 natural and artificial lakes, which make a median of 1557.5 m^3 water available per person per annum [7]. The geographical location of the country creates a favorable climate with a relatively high amount of rainfall when compared with countries in the sub-Saharan African region. Inline with this, the Ethiopian irrigation system has shown great advancements to assure Ethiopians livelihood through increased irrigation development 15.4% [8].

Consequently, the Ethiopian government and people believe that irrigation can play a significant role in food security enhancement and economic growth. However, several factors such as lack of water control infrastructure, lack of technical experts to support irrigation development, and government's low priority to the productive use of irrigation water. Therefore, concrete actions are necessary for it to be included among the important political-economic priorities to improve the irrigation systems in Northwestern Ethiopia. One strategy is to scale back water demand by adopting conservation programs and improving water use sustainability and efficiency. This policy has the advantage that the income may be available to finance developments of sustainable irrigation system [9]. Irrigation water and its management are becoming progressively important. In principle, water valuing policies ensure the potential to alleviate water inadequacy. It is believed that water pricing can play a major role in using irrigation water economically [10].

Several elements, however, have a role. Ethiopia's irrigation infrastructure is outdated, resulting in low agricultural yields and low irrigation water resource usage [11]. The sensible experience of estimating households' willingness to pay (WTP) and collecting fees for irrigation water use in Ethiopia is low [12]. According to [13], Awash geographical area is the only basin in Ethiopia where irrigation water pricing is practiced. Therefore, this low experience of fees payments for irrigation water use can be one reason for the less productive use of irrigation water in Ethiopia [14, 15]. This is the basis of our study, where we estimated farmers' WTP for sustainable irrigation water use.

In recent years, Ethiopian government has focused on the designing of sustainable irrigation water use and a measure of various activities to boost the irrigation system through mainly specializing in the supply side of irrigation [10]. However, the important need for fulfillment within the improvement of irrigation water use system is sufficient knowledge about farmers' WTP for sustainable irrigation water use [16]. As a result, implementation of such policy decisions should specialize in demand as opposed to supply-side thereby regulating the pricing mechanisms and considering the WTP of the irrigation water users [17]. Consequently, the need of estimating farmers' WTP for improved irrigation water use is timely research to enhance irrigation systems. To enhance food security, employment creation, and poverty reduction, Ethiopia is embarking on the development of latest irrigation schemes and also the rehabilitation of the prevailing ones. Information and/or knowledge on the farmers' demand for irrigation water and their WTP for its use is important when planning for effective water management and sustainable irrigation schemes. Such information additionally was needed to facilitate benefit–cost analyses of investments in irrigation and when determining optimal distribution of water resources between different users.

Amhara National Regional State is one of the water potential regions of the country for small-scale irrigation characterized by a low level of investment in irrigation infrastructure [18]. *Gumara* irrigation scheme is one of the irrigation potential sites of the region [19]. It plays a central role in pushing the assembly production to an extent that helps to support local livelihoods and reduce poverty, and mitigate the short supply of food elsewhere within the country [20]. The water is not year-round because the schemes face several water-use problems like inadequate acquisition which results in insufficient supply of water, unfair allocation, conflict between users, and lack of a well-designed distribution service which ends up in higher water wastage [21].

Furthermore, there is a severe lack of fuel for pumping water to farmlands for irrigation. Overall, these difficulties pose a major concern at a time of year when consumers want more water for irrigation [22]. Farmers are irrigating the identical forms of vegetables across the schemes, and their demand for irrigation is the same across seasons and Kebeles, this makes the matter severe [23]. It is possible that at a minimum of scale back, these problems can be solved by improving the present irrigation water use, by creating and operating physical structures such as small dams, improving the distribution system through constructing the properly lined canals. By considering these cases, a hypothetical program can be designed to supply sustainable irrigation water use based on nonvolumetric measures. This might be done if and only if the irrigation users are willing to cover the cost to maintain sustainable and efficient irrigation water service uses. Consequently, there is the need of analyzing the farmers' willingness to pay for sustainable irrigation water use and timely research to improve irrigation systems.

2. Materials and Methods

2.1. Description of the Study Area. The study was conducted within the *Gumara* irrigation scheme which is found in *Dera* and *Fogera* districts of Ethiopia. The name *Gumara* irrigation scheme is originated from Gumara River which is found in South Gondar which extends from Mount Guna from the east to Lake Tana within the west. *Fogera* is a district within the Amhara National Regional State and is found within the South Gondar administrative zone bordering Lake Tana (the source of Blue Nile). The high proportion of plain topography creates a chance for irrigation (as indicated in Figure 1). The altitude ranges from 10°24 and 11°10 and within longitude 2°35 W and 2°75 W. The mean annual rainfall is 1215 mm and ranges between 1100 and 1340 mm with annual average temperature of 24°C [24].

Dera and Fogera districts are locations of the irrigation schemes and are additionally located within the south Gondar zone and is bordered to the south by the *Abay* River which separates it from the west *Gojam* administrative zone. To the west, it is bordered by Lake Tana, to the north by *Fogera*, and to the east by *Estie* district. *Dera and Fogera* districts cover a complete area of 158,948 hectares, and they have about 22,550 hectares' irrigated land and traditional irrigation practice and indigenous irrigation knowledge. The altitude of the districts ranges from 1500 meter to 2600 meter above water level, while the annual average rainfall is 1250 mm. As to the agro-ecology, 85% is *Woyn Dega*, while 15% is *Dega* [24].

Generally, *Dera* and *Fogera* are the most agricultural productive districts in the south Gondar. The agriculture in all Kebeles is a mixed crop-livestock farming system. Crop production is rainfed during the rainy season, supplemented for some households by small-scale irrigation in the dry season. The main crop types grown in the study area are rice, teff (Eragrostis), wheat, barley, maize, beans, peas, chickpeas, and lentils. In irrigated agriculture production, they commonly produced vegetables such as onion, tomato, potato, pepper, and cabbage. Furthermore, there is little irrigation water use improvement in all irrigation Kebeles.

2.2. Sources and Methods of Data Collection. This study was used to collect the data for both primary and secondary data sources. Primary data were collected from the sampled household heads using structured questionnaire through face-to-face interviews. Secondary data were also gathered from the *Fogera* irrigation engineering office and *Dera* irrigation office, and other unpublished different reports. Before the main survey, the questionnaire was translated into the Amharic language (the study area native language) to ease the data collection process and biasedness and data collection errors.

The data were collected by using well-trained personnel and experienced enumerators in 2020 cropping season. Before starting the particular survey, trainings were given to the enumerators about the target of the study and the way to manage the contingent valuation survey questionnaires. Besides, a pilot survey was undertaken to test the performance of the enumerators' understanding of the questionnaires and customization of the questionnaire into the local context.

It was conducted on 18 randomly selected households before the main survey were used to check the validity of the questionnaire. In addition, the main purpose of this survey was to determine the initial bid and to have better understanding of how the actual survey should be conducted. Moreover, adjustment and corrections were made for a clear understanding of the interviewers and the respondents. The focus group discussion and the key informant interview were held to make a decision on the initial bid values during the primary draft questionnaire preparation. After the required adjustment was made to the draft questionnaire, the final questionnaire was developed. Accordingly, three most-often stated values were used as initial bid values for the double-bounded dichotomies choice CVM format. So the average WTP of 550 ETB and the three repeated WTP values l.e.500, 600, and 700 ETB were used as initial bid per year per 0.25 hectares of irrigable land since the average land size of the command area is 0.25 hectare.

Using close-ended, double-bounded dichotomous choice contingent valuation method (CVM) elicitation format and following Mitchell and Carson [25], households were fairly assigned to at least one of the initial bid values to attenuate the place to begin bias. Sets of followed-up bids were determined by the primary response "Yes" and halved if the second response is "No," following [26] guidelines. In view of this, three starting bids of 500, 600, and 700 ETB were randomly allotted to 288 sampled households in the final survey. If the respondents agreed to pay the offered bid, the follow-up bid is doubled and in case of a no response, the respondents are offered a bid that is half of its initial value. Additionally, open-ended CVM was used to determine sample households' maximum WTP for the hypothetical nonmarketable irrigation water use beyond their will not willingness to pay was employed.

2.3. Sampling Techniques and Sample Size Determination. The sample size would be determined by considering resource constraints, time, representativeness of sample, and the purpose of such educational research. For such a quantitative research, the probability sampling technique is more advantageous than the nonprobability sampling technique. Accordingly, a systematic random sampling technique was used to select the sample households of this study. The study was conducted in three potential Kebeles under the command area of *Gumara* irrigation schemes, which have a high irrigation potential in Dera and *Fogera* districts. Kebeles which had more or less improvement in irrigation water use are not considered for choosing as sample because the selected Kebeles must have the identical existing irrigation water use. The three potential Kebeles selected as a sample were *Kuhar Michael*, *Shina*, and *Jigna* Kebeles, and then individual respondents were selected from each of the sample Kebeles. In each sample Kebele, a list of households was generated from Kebele administrations to develop the sampling frame. After the sample frame development, systematic sampling was employed by randomly selecting one sample household (interval) and then selecting every nth interval until the required sample size was reached, since it was incapable of accessing all households listed in the study, and it is the most efficient method than all the others when the variance of the sample is more than the variance of population. The interval (n^{th}) was determined when the target population was divided to the required sample size in advance. Thus, 300 households were selected based on probability proportionate to population size technique as indicated in the table below. Therefore, the overall sample size was distributed to every selected Kebeles, based on the proportion of *Gumara* River

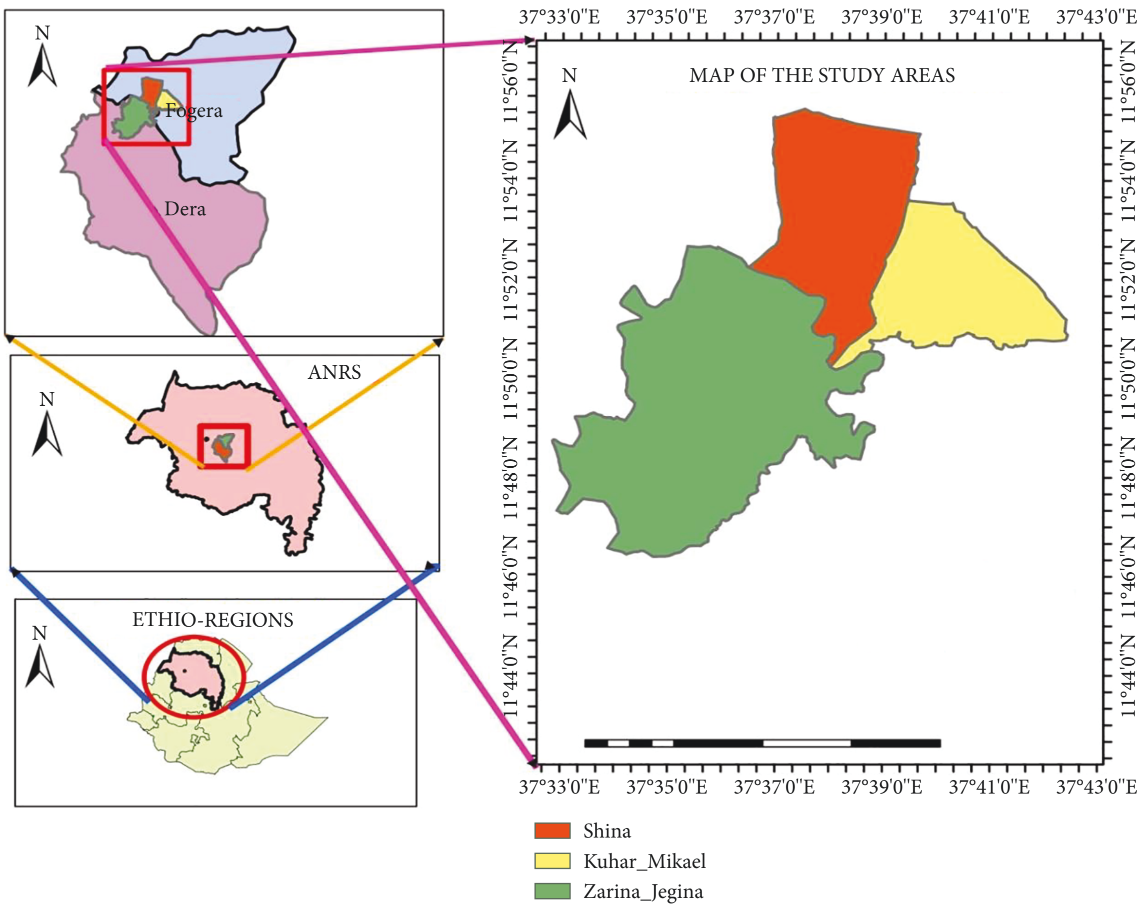

Figure 1: Map of the study areas.

irrigation beneficiaries in each Kebeles as shown in Table 1. During this study, the sample size was determined based on the following scientific formula [27]:

$$n = \frac{N}{1 + N(e)^2} = \frac{1171}{1 + 1171\,(0.05)^2} \approx 300, \quad (1)$$

where $n = 300$ is the sample size; $N = 1171$ is the population (*Gummara* irrigation users); $e = 0.05$ is the level of precision for this study and the level of statistical significance (allowable error = our willingness to accept a type I error), hence the dependent variable is categorical.

Finally, by using proportional allocation method, the researchers decided to take sample households from the selected Kebelles. These sample households were drawn for the data collection using systematic sampling method. The study would have benefitted from higher sample size, but due to inadequate funding, the sample size could not be increased, and the abovementioned sample is representative, since the ratio of sample size to the number of households in the sample zones (300/1171 = 0.256) is greater than the margin of error (5%) that the study was used.

2.4. Method of Data Analysis

2.4.1. Double-Bounded Contingent Valuation Method. The irrigation sustainability scenario is presented for the respondents during the data collection period in such a way by considering the present unsustainable irrigation water use system problem there's a program intended to create change in irrigation water use through the mechanisms of constructing a little dam, and canal which will cover more than 1,820 hectares of farmland. Besides, it's also intended to point out legal frameworks to convey fair irrigation water allocation services between irrigation users. However, once the irrigation project improved the irrigation water use mentioned above, money is required for maintaining the services provided for the longer term use. This money should be covered by the beneficiary households within the command area. So, you may be charged an annually irrigation water fee supported the hectare of land irrigated. Thus, to maximize the advantages from the improved service, irrigation beneficiary households within the command area should contribute money for the use of irrigation water to stay up the sustainable use of the irrigation dam and canals likewise as sustain the implementation of legal frameworks of irrigation schedule.

There are different elicitation methods for the environmental resources and the CVM (its **flexibility** and **adaptability** to many nonmarket valuation tasks that very few valuation techniques can handle. Based on the hypothetical markets that can be flexibly defined by researchers according to the specific characteristics of the public services in question, the respondents of valuation surveys are invited to directly state their preferences and to reveal their

Table 1: Sample size distribution across selected sample Kebeles.

Name of selected Kebeles	Number of the user population	Number of user sample farmers
Jigna Kebele	630	161
Kuhar michael Kebele	248	64
Shina Kebele	293	75
Total	1171	300

willingness-to-pay for the specified qualities or quantities of improvement. The contingent valuation method is used to measure not only the use value but also other intangible values from the improved public service, such as the nonuse value and especially the existence value. The applicability of this method is larger compared with other valuation methods in terms of completeness. This is the earliest valuation technique of stated preference based on a survey that gives the respondents a choice to make an economic decision on nonmarket goods. That is, the valuation is contingent upon the elicitation method and upon the simulated market presented to the respondent [9, 28]. A contingent valuation could be a method of estimating the value that a person places on a good, habitually one that's not sold in markets, like environmental quality or physiological condition by asking people directly what they would be WTP for the stated improvement [29]. There are four CVM elicitation approaches of respondent's WTP, that is, open-ended, biding game, dichotomous choice, and payment card method for monetary valuation of the use and nonuse environment resources [30].

These approaches, however, have their own advantages and disadvantages. Several studies such as that were conducted by Angella, Dick [9, 15, 17] who made a study regarding irrigation improvement that focused on open-ended, follow-up inquires to quantify the maximum amount the farmers are WTP for the improvement of irrigation water use. For this method, simple descriptive statistics can be used to calculate mean, mode, median, and aggregate WTP of farm households. However, open-ended contingent valuation questions are doubtful to produce the foremost reliable valuations because responses to open-ended questions are unreliable and biased [31, 32].

Many contingent valuation studies relay on single-bound dichotomous choice (SBDC) approach within which respondents are asked whether or notthey might accept a randomly assigned predetermined single-bid amount. Although, SBDC is simple to implement, the static is vulnerable to several biases and highly statistically inefficient [26]. A double-bounded dichotomous choice (DBDC) approach during which the respondent is asked a follow-up question if she/he would pay the next or lower bid wishing on the response to the initial bid [33] is sometimes accustomed to improve the efficiency. Thus, we opted to design a DBDC questionnaire in accordance with Hanemann, Loomis [33] and Cameron and Quiggin [26]. If the respondents agreed to pay the offered bid, the follow-up bid is doubled, and in case of a no response, the respondents are offered a bid that is half of its initial value. First, the number of responses is increased so that a given function is fitted with more data points. Second, in the double-bounded dichotomous choice question for each person, we have an initial bid and one follow-up bid. Based on a double-bounded dichotomous choice CVM, there are four possible outcomes: (1) both the first and second answers are "yes-yes"; (2) both the first and follow-up answers are "no-no"; (3) a "Yes" for the first question and followed by a "No" for the second CVM question (Yes-No); and (4) a "No" for the first question and followed by a "Yes" for the second question (No-Yes). The DBDC formats the two responses (Yes-No, No-Yes responses) and makes clear the bounds on unobservable correct willingness-to-pay. Finally, based on DBDC contingent valuation survey, questionnaire for the first and second WTP questions result is "No" and both the first and second WTP questions response is "Yes" combinations, and statistical efficiency comes from the fact that they truncate the distributions where the respondent's willingness-to-pay is likely to reside. Moreover, in order to dictate further the maximum amount of WTP and make comparison with DBDC elicitation result, open-ended questions were asked according to the scheme shown in Figure 2.

Therefore, DBDC elicitation format presents two binary questions for every sample respondent with a sequence of questions to estimate economic value of irrigation water. In this elicitation method, the second question entirely depends on the response of the first WTP questions for supply of irrigation water in the hypothetical market. That is supported by the respondents' initial response, and they are asked new bids; some amount higher than the first bid if initial response was "Yes," and some amount lower, if their response was "No" iteratively. This method increases efficiency compared to the one dichotomous choice model and thus the No–No pairs also improve efficiency gain, and also the amount of responses increased, which helps in fitting a given function than to more observations [34]. Furthermore, the DBDC formats of the study was used for adequate economic valuation and implementation of irrigation water pricing which is clearly shown and summarized in Figure 2.

Those who answered No-No within the survey are required to supply their reasons for not WTP, and thus the explanations are recorded in an open-ended format. The common problem within the contingent valuation methodology is that the hypothetical bias (Hypothetical bias is a case where respondents either not pay or pay less when compared to the real-life situation), where the hypothetical WTP for the irrigation water use system overestimates the important WTP. Hence, to reduce the bias, the hypothetical scenario was developed being assisted by an expert, and native and professional enumerators were hired and trained within the context of this research questionnaires. Finally,

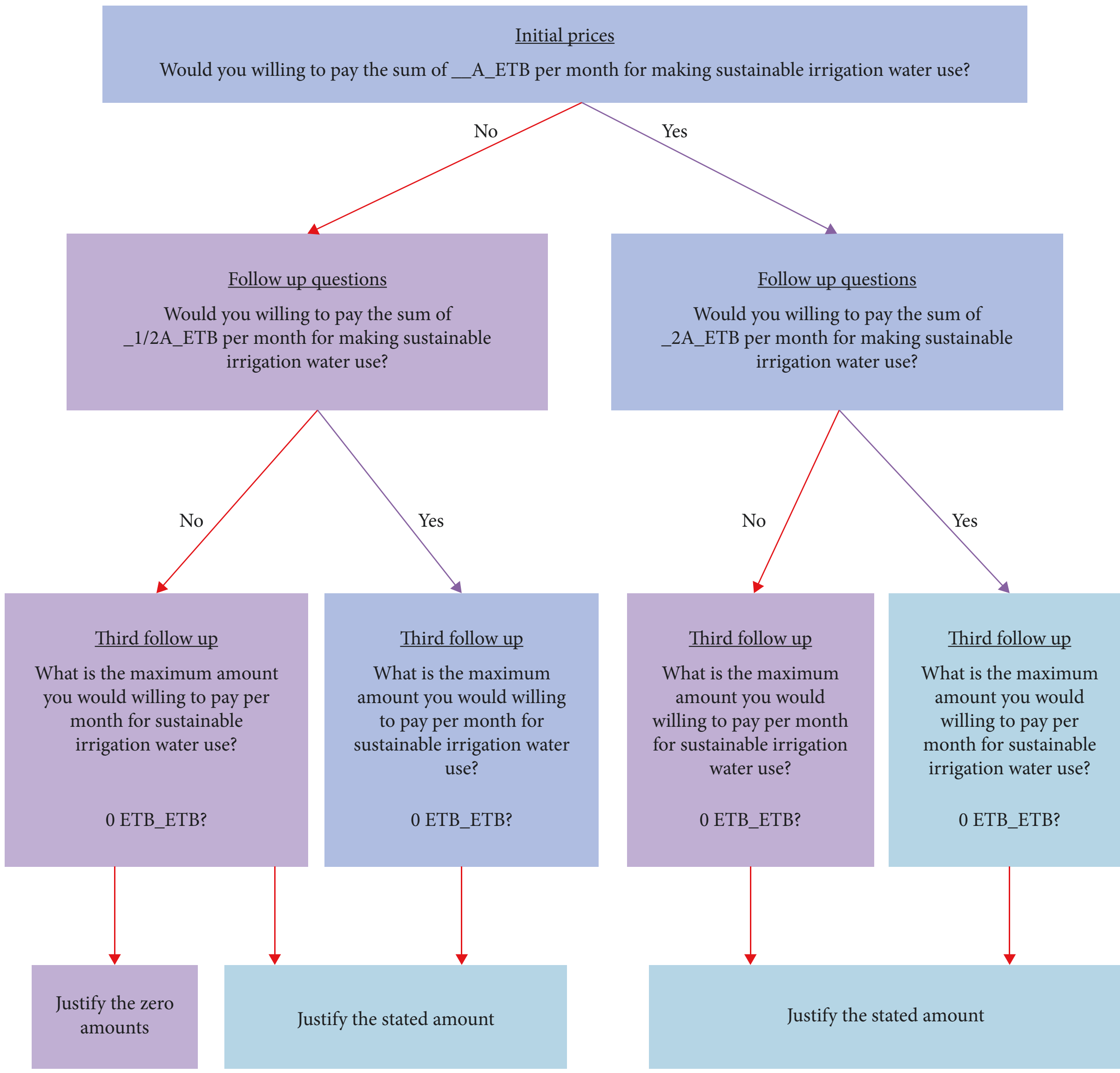

Figure 2: Set of responses for DBDC approach.

the quantitative data were gathered by using face-to-face semistructured questionnaire that was applied to collect the primary data from the underlined sample households. Focus group discussion and the key informant interview were also held as a part of primary data for the qualitative part and as a means of triangulation for the quantitative data. In relation with the topic, the questionnaire was designed by using the CVM. There is no standard approach to the design of a contingent valuation survey, although virtually all contingent valuation surveys consist of several well-defined elements. The questionnaire was administer based on Gelo and Koch's [35] recommendations to elicit WTP of respondents: (1) an introductory section which helps set the general context for the decision to be made; (2) a detailed description of the hypothetical scenario description of the terms under which the good or service is to be offered to the respondent; (3) the institutional setting in which the good will be provided (actual survey design and decide a payment/compensation vehicle to determine how much the respondent values a good or services); (4) actual survey implementation in which the good will be paid for; (5) a method by which the contingent valuation survey produces the respondent's preferences with respect to the hypothetical scenario; (6) briefing questions about why respondents answered DBDC questions the way that they did; and (7) estimating and aggregating economic benefits (the **TWTP**) for the population for use in **TWTP** (**mean WTP** $*$ **N)** which means by multiplying the population by the mean WTP.

During data collection, the ethical issues got critical attention and then the respondents were approached; we explained the aim of the study and guaranteed them, that their responses are kept confidential. Then following this, we would be able to obtain consent and willingness to participate within the survey. Additionally, the study also assures that there's no used material without source citation or crediting or improper paraphrasing of materials.

2.4.2. Descriptive Analysis. Descriptive statistics including percentage, frequency, mean, minimum, and maximum were computed to present the mean and aggregate willingness-to-pay status of sample households.

2.4.3. Econometric Model Specification. The binary probit econometric model is efficient and unbiased to estimate the coefficient of independent variables for the single-bounded dichotomous choice model, whereas the bivariate probit econometric model is efficient and unbiased to estimate the coefficient of independent variables for the double-bounded dichotomous choice model. Therefore, the bivariate probit model is a joint model for two binary outcomes with correlated error terms, in the same way as for seemingly unrelated bivariate probit regression model [36]. The seemingly unrelated bivariate probit regression model takes two independent binary probit models into account and estimates them together by considering their nonzero correlation of error terms between two equations. However, binary probit regression model can produce unbiased, but inefficient estimators for exogenous variables, because it assumes the error terms are not correlated with each other, and it also ignores the unobservable heterogeneity between the two equations. Hence, an alternative approach to control for unobservable heterogeneity is to consider a seemingly unrelated bivariate probit regression model provides a way of dealing with two separate binary dependent variables.

The other comparative advantage of the seemingly unrelated bivariate probit regression model is to calculate the mean level of farmers' WTP for improved irrigation water use. Therefore, in this study, a seemingly unrelated bivariate probit regression model was employed to quantify their mean WTP in two bid levels jointly. The marginal effects and predicted values for farmers' probability of WTP in the two separate binary outcomes could be estimated similar to those for the binary probit models. Marginal effects for the joint probability, say P ($y_1 = 1$ and $y_2 = 1$) are also available.

Inquiring about the respondents' WTP directly is the standard method in most CVM studies, but inquiring about the payment amount, that is, open-ended method, is not suggested. This study focuses on the closed-bounded method to elicit the WTP, that is, to ask the respondents WTP under a given amount. This study uses the DBDC format by a following-up questionnaire, and this implies that although the outcome of the event is discrete, the multinomial logit or probit model would fail to account for the nature of the response variable [26, 33]. Let I^1 and I^2 be the first bid price and the second bid price, respectively. Then the WTP can be bounded in $I^1 \leq WTP < I^2$ for the yes–no responses; $I^1 > WTP \geq I^2$ for the no–yes responses; $WTP \geq I^2$ for the yes–yes responses; and $WTP < I^2$ for the No–No responses. The most general econometric model for the double-bounded contingent valuation data comes from [34], formulations:

$$WTP_{ij} = \mu_i + \varepsilon_{ij}, \tag{2}$$

where WTP_{ij} = is the jth respondents WTP; $i = 1, 2$ represents first and second answers; $\mu 1, \mu 2$ = are the mean value for the first and second WTP questions repectively; εij = un observable random component which follows and assumes $\varepsilon ij \sim (0, \delta^2)$.

The bivariate probit model, the random effects probit model [37], and the interval-data logit model [33] are as proposed by Cameron and Quiggin [26]. According to [38], estimates of bivariate probit model is preferred to that of interval data logit, when the correlation coefficient between the two consecutive bid error terms is close to zero. Therefore, after checking the correlation coefficient for the first and second responses, the study used bivariate probit model (To estimate bivariate probit model, the mean of initial question $\mu 1$ and the second follow-up questions $\mu 2$ are assumed independent, and the covariance's are assumed zero.) to estimate the mean WTP and aggregate WTP for sustainable irrigation water use.

In using DBDC elicitation method, the bid function model is described, where binary choices data from the bids are used to estimate the WTP values. The second question involves the acceptance of another amount depending on the first WTP answer. The study assumes the unobserved WTP of the respondent i, WTP_i^0 in first question is between the lowest WTP value (WTP_i^l) and the highest WTP value (WTP_i^h). The DBDC elicitation approach is better than SBDC and other elicitation methods, since we might have four types of results from the follow-up question by respondents' reply of "yes "or "no". (1) Yes–Yes means "yes" for the bid price in first and second question, and the highest WTP in the mind of respondents will be between WTP_i^h and infinity; (2) Yes–No presents "yes" for the first bid price, but "no" for the second price, thus the highest WTP is between WTP_i^o and WTP_i^h; (3) No–Yes means "no" for the first bid price, but "yes" for the second price, and the highest WTP is between WTP_i^l and WTP_i^o; (4) No–No means "no" for both of the two questions, and the highest WTP will be between 0 and WTP_i^l. To construct the likelihood function, the probability of observing each of the possible two bid response sequences (yes–yes, yes–no, no–yes, no–no) is given as follows: the probability that the respondent i answers to the first bid and the second bid is given by Lin, Fu [39] the four types can be expressed by the following equations:

(a) $pr(yes, no) = (WTP1i \geq t^1, WTP2i < t^2) = pr(\mu 1 + \varepsilon 1i < t^1, \mu 2 + \varepsilon 2i < t^2)$,

(b) $pr(\text{yes}, \text{yes}) = (WTP1i > t^{1,}, WTP2i \geq t^2) = pr(\mu 1 + \varepsilon 1i > t^1, \mu 2 + \varepsilon 2i \geq t^2)$

(c) $pr(\text{no}, \text{no}) = (WTP1i < t^1, \quad WTP2i < t^2) = pr(\mu 1 + \varepsilon 1i < t^1, \mu 2 + \varepsilon 2i < t2)$

(d) $pr(\text{no}, \text{yes}) = (WTPli < t^1, \quad WTP2i \geq t^2) = pr(\mu 1 + \varepsilon 1i < t^1 \mu 2 + \varepsilon 2i \geq t^2$

The i^{th} contribution to likelihood function becomes:

$$Li\left(\frac{\mu}{t}\right) = {}^{*}pr\left(\mu 1 + \varepsilon 1i \geq t^{1}, \mu 2 + \varepsilon 2i < t^{2}\right) - -\text{Yes} - \text{No},$$

$$^{*}pr\left(\mu 1 + \varepsilon 1i > t^{1}, \mu 2 + \varepsilon 2i \geq t^{2}\right) - - - -\text{Yes} - \text{Yes}, \quad (4)$$

$$^{*}pr\left(\mu 1 + \varepsilon 1i < t^{1}, \mu 2 + \varepsilon 2i < t^{2}\right) - - - -\text{No} - \text{No},$$

$$^{*}pr\left(\mu 1 + \varepsilon 1i < t^{1}, \mu 2 + \varepsilon 2i \geq t^{2}\right) - \text{Nes} - \text{Yes}, \quad (5)$$

where

(i) t^1 First bid price
(ii) t^2 second bid price
(iii) Yes − No = 1 for yes, no answer, 0 otherwise
(iv) Yes − Yes = 1 for yes, yes answer, 0 otherwise
(v) No − No = 1 for no, no answer, 0 otherwise
(vi) No − Yes = 1 for no, yes answer, 0 otherwise

This formulation is referred to as the bivariate discrete choice model that assumes normally distributed error terms with mean 0 and respective variances $\sigma 1^2$ and $\sigma 2^2$, then WTP1j and WTP2j have a bivariate normal distribution with means $\mu 1$ and $\mu 2$, variances $\sigma 1^2$ and $\sigma 2^2$, and correlation coefficient ρ. Given the DBDC questions response to each question, the normally distributed model is represented as a bivariate probit model. The i^{th} WTP response contribution to the bivariate probit likelihood is given as follows:

$$L\left(\frac{\mu}{t}\right) = \phi\varepsilon 1\varepsilon 2\left(d1i^{t^{(1-\mu)/\sigma 1}}\right), \left(d2i^{\left(t^{(1-\mu)/\sigma 2}\right)}\right), d1id2i\rho, \quad (6)$$

where $\varphi\varepsilon 1\varepsilon 2 =$ the bivariate normal cumulative distribution; function d1i $= 2y1i - 1$ and $d2i = 2y2i - 1$; $y1i = 1$ if the response to the first equation is yes and 0, therwise; $y2i = 1$ if the response to the second equation is yes and 0, otherwise; ρ = coorlation coefficient &; σ = standard deviation of the error;

According to Loomis, Hanemann [40], one of the main objectives of estimating empirical WTP based on the contingent valuation survey response is to calculate mean WTP distribution. Then after running a regression of dependent variable of two equations (yes–no indicators), on a constant and on independent variables consisting of the bid levels, the mean WTP value was calculated following the approach developed by [41]. Therefore, the mean WTP value of improved irrigation water can be calculated as follows (Equation (7)):

$$\text{Mean}\, WTP = \frac{x'\beta'}{\mu o\prime}, \quad (7)$$

where x' = raw vector of a sample mean including 1, for the constant term, $\beta'^{(k-1\times 1)}$ = estimated coefficients. $\mu o'$ = coefficent on the bid variable. $x' = 1$ & β is the coefficient in the constant term.

For an open-ended contingent valuation survey, responses from maximum WTP figures reported by the respondent can simply be averaged to produce an estimate of mean WTP and could be estimated following [34] as follows:

$$\text{mean}\, WTP = \sum_{i=0}^{n} \frac{yi}{n}, \quad (8)$$

where n is the sample size and y is the maximum *WTP* pay reported by households; yi is the maximum amount of an individual *WTP* for the proposed improvement.

3. Result and Discussions

3.1. Households' Willingness to Pay Status for Sustainable Irrigation Water Use. First, it is necessary to distinguish between responses that can be considered as valid and those that appear "invalid" (By **"invalid**," we mean responses that were actually excluded from the regressions because they lacked the required information for further analysis.). As presented in Table 2, the data were collected from 300 sample respondents, but only 288 respondents were used for statistical analysis since 12 observations were eliminated as invalid responses. The distribution of the invalid responses across sample Kebeles shows that 5, 3, and 4 questionnaires were not relevant for further analysis in *Jigna* Kebele*, Kuhar Michael* Kebele, *and Shina* Kebele, respectively. Those protests attached the scenario with political issues, and they gave the wrong responses when they were asked to state their WTP based on the criteria of the report of the NOAA panel on a contingent valuation method by Arrow, Solow [31], which suggested that a respondents' willing-to-pay stated the amount they might answer as being undesirable, if the respondent believes the proposed scenarios distributed the load unfairly, misgiving on the feasibility of the planned action and refusal to accept the hypothetical choice problem. Therefore, the result and discussion are made based on 288 respondents who gave a valid response.

As [42] recommended, prior to the elicitation question, individuals were asked if they might pay anything. As a result of the solicitation of the DBDC contingent valuation, individuals were asked "yes" or "no" questions to assess their WTP for improved irrigation water use. About 98.26% of the respondent were willing to pay money for the proposed irrigation project and also the remaining about 1.74% of them were not willing to pay for the hypothetical improved irrigation project (as indicated in Table 3). Those who failed the WTP considered the economic reason might be treated as having true zero WTP [14, 43].

After assessing the households' willingness to participate in cost recovery for irrigation water sustainable use, the households' unwilling to participate were asked the reason for their unwillingness to participate. Those unwilling household heads reported that they could not afford to pay money for the proposed improvement. Those that did not show a WTP because of the economic reason may well be treated as having true zero WTP [44, 45]. Those households, who were not WTP, were asked to state the rational for their unwillingness to obtain for the proposed sustainable irrigation water use project. The responses were given in Table 4.

Table 2: Households' willingness-to-pay status for sustainable irrigation water use.

Name of selected Kebeles	Number of the user population	Number of user sample farmers	Invalid responses
Jigna Kebele	630	161	5
Kuhar Michael Kebele	248	64	3
Shina Kebele	293	75	4
Total	1171	300	12

Source: own survey, 2020.

Table 3: Respondents' willingness-to-pay for the proposed sustainable irrigation project.

Willingness to pay	Number	Percent
Willing	283	98.26
Unwilling	5	1.74
Total	288	100.00

Source: survey data, 2020.

As presented in Table 4 about 1.74% of households were unwilling to pay anything for the hypothetical nonmarketed water resource sustainable use. So their willingness to pay was considered as zero. A number of the respondents stated that management would misappropriate the cash. Others said the cost of agricultural production under the scheme was too high, the land sizes were too small, and irrigation water is not well distributed, crop yield was too low in irrigation reason, and water was not fairly distributed in a reasonable way. Others too cited prevalence of crop diseases. During this case, misappropriation of the funds sounds and looks like protest because the respondents seem to possess value for the project, but undecided that the funds are used for a cause.

3.2. Joint Responses of Households' WTP. As [46] explained efficiency within the elicitation of WTP may be increased if repeated questions are used. Table 5 depicts the joint response of sample households for the first and also the next minimum or maximum bids. The result revealed that, about 43.75% of households were willing to pay the maximum amount beyond the stated bids in both the first bid and second bid values (Yes–Yes). Whereas for respondents who were willing to pay in the first bid and not willing to pay in the follow-up maximum bid values (Yes–No) were 26.06%. The proportion of households who were not willing to pay in first bid and willing in the second maximum bid (No–Yes) was found to be 9.37%, and also the remaining 20.84% of respondents were felt to No–No (who are not willing at both level of bids).

3.3. Estimation of Mean Willingness to Pay. In the practice of CVM, zero bidders are presented with follow-up, open-ended inquires to ascertain whether or not they are expressing a protest bid against the valuation or they place no value on the resource [47]. Accordingly, the results of the contingent valuation survey revealed that the mean WTP of sampled households was about 926.7 ETB (€25.05) with the ranges from 0 to 3000 ETB annually for the development of sustainable irrigation water use system (as indicated in Table 6).

3.4. Estimation of Mean from Double-Bounded Dichotomous Choice Format. As Table 7 depicts, the significant and positive sign of Rho (ρ) indicates the existence of positive relationship between the two WTP responses. This is significant, but the imperfect correlation between the two error terms verifies that the seemingly unrelated bivariate probit model is the correct econometric model to estimate mean WTP data collected from DBDC contingent valuation questionnaire. The likelihood ratio test of the model confirms the interdependence between two probit equations at less than a 1% significance level. This indicated that the two equations estimated concurrently. Because the model result indicated that both the initial and also the follow-up bid had a statistically significance at less than a 1% significance level. The probability of WTP only in the second response (WTP2) by the sample households was about 57.85%. As against this, the joint probability that household heads fail to WTP in both of the responses is about 13.11%, and this indicated that they are more likely to fail to WTP in both responses (WTP1 and WTP2) simultaneously. Moreover, the regression output in Table 7 revealed that the coefficient of the initial and follow-up (second-bid values) have negative values and significance at less than 1% significant probability level, respectively.

The mean WTP estimation in double-bounded dichotomous choice was made based on WTP in first and second bid values through the subsequent Krinsky and Robb [41] procedure. The mean level of farmers' WTP was found to be 950.7 ETB (€25.69) annually. Whereas the descriptive statistics from open-ended questions indicated in Table 6 that the mean level of user farmers' WTP was found to be 926.1 ETB (€25.03) annually, and this is a smaller amount than the mean WTP from the double-bounded dichotomous choice format. This comparison result's in step with the finding of Aman, Shumeta [10], who suggested a possible reason that households become a free rider within the open-ended CVM questions.

This implies that at 95% confidence interval, the mean WTP varies between (−0.001269__0.0002482) ETB per hectare/year. However, the rational being the very fact that the second-equation parameters are likely to contain more noise in terms of anchoring bias where the respondents are assumed to take.

3.5. Estimated Aggregate Farmers' Willingness to Pay. As indicated in Table 8, one among the last main objectives of WTP contingent valuation study is to estimate the aggregate

Table 4: Number of zero willingness-to-pay bids with reasons.

No.	Reasons for unwillingness to pay	Total	
		No.	%
1.	Management of the money and will be misappropriated	1	20
2.	Cost of agricultural production through irrigation is too high	1	20
3.	Land sizes are too small and water is not well distributed	2	40
4.	Crop yield is too low because of the prevalence of crop diseases	1	20
	Total	**5**	**100**

Source: survey data, 2020.

Table 5: Joint responses of households' willingness to pay.

Joint responses	Number	Percent
Yes–yes	126	43.75
Yes–No	72	26.04
No–Yes	27	9.37
No–No	63	20.84
Total	288	100.00

Source: survey data, 2020.

Table 6: Households' minimum, maximum, and mean willingness to pay for better irrigation water.

Variable	Obs.	Mean	Std. Dev.	Min	Max
Maximum willingness to pay	288	926.059	639.842	0	3000

Source: survey data, 2020.

WTP of the goods valued or the analysis of welfare measures using the value of total WTP obtained from the sample households to the whole population within the irrigation command area. For a valid analysis of the advantages, the various biases of the sample design during contingent valuation study has to be minimized and protest zero responses should be excluded from the data [48]. Lastly, as indicated in Table 8, the National Oceanic and Atmospheric Administration (NOAA) convened and established a panel of prominent social scientists in 1992 to assess the reliability of contingent valuation (CV) studies. The product of the panel's deliberations was a report that laid out a set of recommended guidelines for contingent valuation survey design, administration, and data analysis. A panel guide following Arrow, Solow [31] protests that zero households are excluded from the aggregation, and hence, we expected none of the various biases within the analysis.

The total farmers' WTP for improved irrigation water use can be estimated by taking the entire number of beneficiary households less the protest zero bidders and their total irrigable land sizes within the command area. In line with key informants of the district agriculture experts and office heads, the total number of irrigated land is estimated to be 372.5, 439.5, and 1008 hectares, and also the total beneficiary households are estimated to be 248, 293, and 630 in *Kuhar Michael* Kebele, *Shina* Kebele, and *Jigna* Kebele, respectively. Consequently, the total amount of willingness to pay for the irrigation project area was calculated by multiplying the mean WTP value obtained from seemingly bivariate probit regression model. The valid number of households was obtained after deducting the expected protest zero responses (20) (The invalid responses are calculated by multiplying the sum total percentage of the protest responses in the sample by the total population in the command area. Expected invalid response $= 0.017 * 1171 = 20$ households. Thus, the valid number of responses were taken from $= 1171–20 = 1151$ households.) from the total population. As a result, aggregate WTP has found to be 6644257.16 ETB (€179574.52) and 6472327.68 ETB (€174927.77) from double-bounded and open-ended questions, respectively. This aggregate willingness to pay result was greater than research findings (156786.1 ETB from double-bound elicitation method and 128264.55 ETB from open-ended elicitation method) [49].

One of the main steps in analyzing data obtained from contingent valuation method is estimating and aggregating benefits. After calculating mean WTP for better irrigation water used as discussed in the above section, next, the total willingness to pay of households was estimated based on the proportion (willing versus not willing households). As discussed overhead, the survey covered 288 sample households and only 283 were valid out of 1171 total user households within the study area. The results of the study show that about 98.26% of the households were willing to pay for better irrigation water use system. Based on the sample mean and willing-to-pay permits, we can generalize the estimates for the entire population's aggregate willingness to pay and the amount of money that will be collected for sustainable irrigation water use. Based on our estimation a total of 1151 ($1171 * 0.9826 = 1151$) households were WTP for proposed irrigation project (column 6). Which is calculated from the total sample of about 98.26% of households that were willing to pay for sustainable irrigation water use and proportionally applied for the entire target population size.

Table 8 presents the number of households in each sample Kebele (columns 6). The stated amounts of WTP for each Kebele, and the total households WTP in that Kebele (column 6). To obtain the WTP for households (column 7 and 8) from open-ended and double-bounded contingent valuation approach, respectively. As discussed in the previous section, the mean WTP from open elicitation and double-bounded method (926.059 ETB and 950.7 ETB/month, respectively), multiplied by the corresponding number of households' willing to pay. Finally, the total willingness to pay (TWTP) was obtained by adding the WTP of the total households in each Kebele (column 7 and 8). The

Table 7: Parameter estimates of a seemingly unrelated bivariate probit model.

WTP	Coef	Robust Std. Err	Z	$P > \lvert z \rvert$	[95% Conf. Interval]
B1	−0.0023819	0.0009627	−2.47	0.003	−0.0042688−−0.0004949
Constant	1.941436	0.5918425	3.28	0.001	0.7814456 3.101425
WTB2	Coef.	Robust std. Err	Z	$P > \lvert z \rvert$	[95% conf. Interval]
B2	−0.0005104	0.0003871	−1.32	0.0087	−0.001269 0.0002482
Constant	0.5545097	0.3694068	1.50	0.133	−.1695142 1.278534
Rho	0.6942757	0.1851148			.1544699 .9148696
Joint probability of success = 0.5785					
Joint probability of failure = 0.1311					
Wald test of rho = 0					
chi2(1) = 5.7393					
Prob > chi2 = 0.0166					
Mean WTP = 950.7					

Source: own survey, 2020.

Table 8: Estimated total willingness to pay from open-ended and double-bounded dichotomous choice.

Stratifications based on the amount of solid waste generated	Total households (No.)	Sample households (No)	Willing-to-pay households		Total households WTP for better SWM	Open-ended total WTP	Double-bounded total WTP
			No.	%			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Kuhar michael Kebele	630	155	152	53.7	619	573230.52	588483.3
Shina Kebele	248	61	60	21.2	244	225958.40	231970.8
Jigna Kebele	293	72	71	25.1	288	273801.6	266704.99
Total	1171	288	283	100%	1151	1072990.52	1087159.09

Source: Survey result, 2020.

result indicated that the TWTP is 1,072,990.52 ETB/month or (€28,999.74) from open-ended elicitation method (column 7), and 1,087,159.09 ETB/month (€29,382.68) from double-bounded elicitation method (column 8). The total WTP across sample of Kebeles were also calculated and result indicated significant amount of difference. The TWP of the *Kuhar Michael* Kebele, *Shina* Kebele, and *Jigna* Kebele of the sample Kebelles were 5,73,230.52; 2,25,958.40; and 2,73,801.6 ETB per month, respectively, from open-ended elicitation method (column 7), and 5,88,483.3; 2,31,970.8; and 2,66,704.99 ETB/month from double-bounded elicitation method (column 8).

3.6. Estimated Aggregate Farmers' Willingness to Pay. The final task in CVM elicitation is to estimate the total amount of households that are willing to pay (aggregate benefits) for sustainable irrigation water use. Thus, how much households are willing to pay is the economic cost of services improvement in the district. To arrive at this, the mean WTP from the sample is extrapolated across the population. The aggregate farmers' WTP for improved irrigation water use could be estimated by taking the total number of beneficiary households less the protest zero bidders and their total irrigable land sizes in the command area. The result in Table 9 shows that respective sample Kebele's key informants, the total number of irrigated land is estimated to be 372.5, 439.5, and 1008 hectares, respectively, and the total beneficiary households are estimated to be 248, 293, and 630 from *Kuhar Michael* Kebele; *Shina* Kebele; and *Jigna* Kebele, respectively (see Table 9).

3.7. Estimated Households' Demand Curve for Improved Irrigation Water Use. The sampled household demand toward the scenario of improving irrigation water use at different price levels could be observed through driving demand curve as shown in Figure 3. The demand curve is derived with the maximum WTP along the X-axis, and the number of sampled irrigation water user farmers that are willing to pay per year along the Y-axis. Moreover, the figure was formulated following some appropriate mathematical equations to get constant (K) ($k = 1 + 3.322\log 288 = 9$, where 288 is sample size/n) and width (W) ($W = (x\max - x\min/k)$; where x max and x min are MWTP, then $W = 333.3$) to set the stated level of maximum WTP class along the "X" axis.

As the monthly payment increases, the number of households willing to pay that price declines (see Figure 3). This relationship can be more easily observed by deriving a demand curve for the improved solid waste management. For this, we measure the class mark along the vertical axis and the number of households willing to pay at least that class mark (WTP midpoint) per month along the horizontal axis. As shown in Figure 3, the demand curve has a negative slope like most economic goods under normal conditions.

Table 9: Estimation of aggregate willingness to pay.

Commanded area	Number of user population	Total irrigating area in hectare
Kuhar michael Kebele	248	372.5
Shina Kebele	293	439.5
Jigna Kebele	630	1008
Total user population	1171	1820
No of protested users	46 (If 12 protest households get from 300 households, then how much protests would be in 1171? Then it would be 46)	72.8

Source: survey data, 2020.

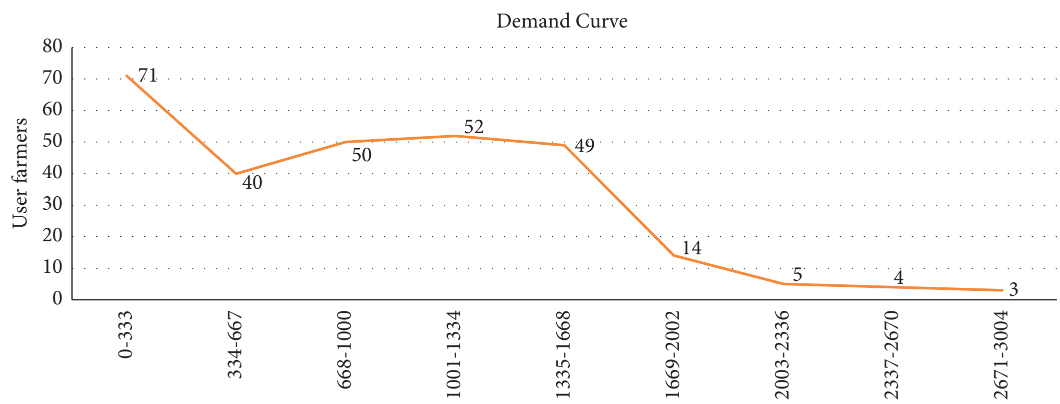

Figure 3: Sample households demand curve Source: survey data, 2020.

This implies that increasing price has a disincentive effect on the demand for improved solid waste management services, keeping all other factors constant. It is in line with the economic theory of demand. The downward sloping of the demand curve implies an increase in the price of the improved irrigation water decreases the quantity demand for the improved irrigation water use system, other things remain constant.

4. Conclusions and Recommendations

4.1. Conclusion. The study attempts to determine the price of sustainable irrigation water use system by eliciting farmers" WTP on *Gumara* Irrigation Project using contingent valuation method. The majority (98.26%) of the households feel that households have to cooperate with government to improve existing condition. From seemingly unrelated bivariate probit model regression results, the mean and aggregate willingness to pay was 950.7 ETB (€25.7) and 1,087,159.09 ETB (€29,382.7) per month and per year, respectively. On the other hand, the mean and aggregate willingness to pay from the open-ended questions were 926.059 ETB (€25.03) and 1,072,990.52 ETB (€28,999.74) per month and year per household, respectively. From these result of the study, the researchers concluded that there are a high degree and level of WTP in the *Gumara* Irrigation Scheme for improved irrigation water use to provide sustainable irrigation water. The estimated total WTP from this study can be considered as the societal benefits of recovering the cost of sustaining water service and can be used in future cost–benefit analysis for policy formulation. Additionally, the estimated mean WTP from an open-ended elicitation format was less than the double-bounded elicitation format that might be due to a human being wanting a free service from the government or the benefit of improved irrigation water use at the expense of others.

4.2. Recommendation. The result from the two stated preference techniques indicates that farm households are willing to pay for irrigation water supply. This result has strong policy implications in that if government designed and implemented a proper pricing of irrigation water in the area, it will avoid inefficient water use practices. It also inculcates a sense of responsibility among the irrigation water users. Moreover, the estimated total revenue the government could get from sustainable irrigation water use system could be used for the societal benefits of recovering the cost of sustaining water services in the command area. This revenue collected from households may assist in financing other projects that assist the development of the country as well as sustainable use of *Gumara* irrigation system. The government should implement irrigation water management practices to supply reliable irrigation water to the farmers and should set up a proper irrigation water pricing as an amount close to the mean willingness to pay that households were willing and able to pay.

Data Availability

The data and publications from this research manuscript will be of open access and available via an online repository for anyone freely.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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