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HOUSEHOLDS' DEMAND FOR GROUNDWATER CONSERVATION: THE CASE OF IRRIGATION PRACTICES IN KOMBOLCHA DISTRICT, EASTERN ETHIOPIA

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Summary

Ground water degradation is the problem, and its management is curial for sustaining the benefit from the resource. To maintain the resource we have to have full information about the value of the resource conservation. Therefore, in this study a contingent valuation survey was conducted in Kombolcha district to elicit households' willingness to pay for groundwater conservation. A sample of 394 households was randomly selected, and interviewed. However, after checked for sample selection bias 4 protest bidders were excluded from the data set. Tobit model was applied to determine the factors affecting willingness to pay. The descriptive analysis shows that about 82% of the respondents reported that the groundwater has being degraded due to population pressure, deforestation, soil degradation, agricultural expansion and climatic change. The mean willingness to pay was computed at 60.63 ETB with the total willingness to pay of 1,689,576.21 per annum. The study determined that monthly income, educational level, total farm land holding, total family size, perception and tropical livestock unit were variables that have significant effect on households' willingness to pay. Thus, socio-economic variables should also be considered while designing water related projects at household level.

Keywords: *Contingent Valuation Method, Groundwater conservation, Tobit model, Willingness to Pay*

JEL*: Q25, Q50, Q51, Q59*

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Introduction

Groundwater is water located below the earth's surface in the saturated zone unlike the surface water (Siebert *et al.,* 2010). It is a valuable renewable natural resource, and its availability depends on economic activities (Emerton and Bos, 2004). Globally, groundwater is an important resource for irrigation practices and hence livelihoods and food security of billions of people (Morris *et al*., 2003). Groundwater aquifers have the potential to be used for anthropogenic carbon dioxide sequestration (Malanson, 1993; FAO, 2003), and indirectly regulate soil erosion (Malanson, 1993). Intensive groundwater uses for irrigation has given rise to satisfy social and economic benefits. However, the poor management and intensive groundwater use has all too often been the causes of groundwater degradation. Groundwater degradation directly and indirectly affected economic activities. The increased pressure on groundwater results in wells drying up and conflict between users (Morris *et al*., 2003). Moreover, only rich farmers can afford to a reliable source of water; and the poorer sectors of society are likely to be the hardest hit as they are the most vulnerable to ecosystem changes. Generally, declining groundwater levels have an impact particularly in the developing world, and forcing women and children to walk long distances to take water resource (FAO, 2003).

Groundwater management is crucial for poverty alleviation, environmental conservation as well as sustaining the benefit from the resource. There has been a growing concern by policy makers, interest groups and the public for the management of groundwater. In order to manage groundwater, among others, more reliable information on the economic value of groundwater conservation is crucial. This study therefore, tried to estimate the economic values of groundwater conservation using contingent valuation method (CVM). A respondent was introduced to a hypothesized market scenario and a willingness to pay (WTP) value. The study provides valuable information on the value of groundwater conservation of Kombolcha district to decision makers and agricultural water users that are affected by the degradation of the resource. It is believed that the study plays a key role in formulation of a successful groundwater policy.

Measuring Welfare Change

The values of environmental resources (like groundwater resource) are measured using its effects on human welfare (Mitchell and Carson, 1989). A weaker, but perhaps ethically more neutral, criteria for welfare measure is Pareto improvement. In Pareto improvement a policy change makes one or more persons better off without making at least one other person worse off (Haab and McConnell, 2002).

Change in environmental goods (from statuesque to improvement) can affect individual's welfare through changes in prices they pay for private inputs and goods, and the quantities of non-marketed environmental goods. This welfare changes can be measured using ordinary consumer's surplus, which holds income constant but not the level of utility. According to Hicks (1943) the welfare changes can also be measured using compensating surplus, compensating variation, equivalent variation

and equivalent surplus. Compensating variation and compensating surplus measure the gains or loss from environmental goods and services, and hold utility constant at the initial level. However, equivalent variation and equivalent surplus measure welfare change and hold utility constant at some specified alternative level. Generally, these four welfare measures involve either payment or compensation to maintain utility at the specified level (Randall and Stall (1980), cited in Mitchell and Carson 1989). If the proposed change is welfare increasing through changes in the quantity of environmental goods, which is the focus of this study, the appropriate welfare measure is the compensating surplus. This measure can be interpreted as the consumer's WTP in order to gain the quantity increase and still maintain their initial utility level (Mitchell and Carson 1989).

In Hicksian demand curve, the demand function for the public good requires accurate market data. But, it is very difficult to obtain accurate market data therefore, contingent valuation method, which requires the creation of hypothetical market scenario that is similar to actual market situation for groundwater conservation was used. From this method we can generate the WTP data without having to estimate the actual demand curve. This concept can be further emphasized from the relationship between the expenditure function and Hicksian compensated surplus measure. According to Haab and McConnell (2002), the expenditure function that provides the theoretical structure for welfare estimation is specified as:

$$y=e(p,q,u)=\min_x \{p.x/u(x,u)\geq u\} \quad (1)$$

Where: $\mathbf{y}$ is the minimum amount of income needed to maintain utility level given the price and public good vectors; $\mathbf{q}$ is the vector of environmental goods; $\mathbf{p}$ is a vector of prices; $\mathbf{u}$ is level of utility when $\mathbf{u = V(p,q,y)}$; $\mathbf{x}$ is the vector of private goods and $\mathbf{y}$ is income. Let $\mathbf{p_0, q_0, u_0, y_0}$ represent some initial level of those respective arguments and $\mathbf{p_1, q_1, u_1, y_1}$ represent some succeeding levels. The derivative of the expenditure function with respect to price gives the Hicksian or utility-constant demand. We can represent the compensation surplus by:

$$\mathbf{WTP = CS = [e(p_0, q_0, u_0)] - [e(p_0, q_1, u_0)]} \quad (2)$$

q_1 is preferred to q_0 for proposed new project brings welfare gain. In this case, the compensated surplus (CS) measure tells us the consumers'' WTP for welfare gain. WTP is the amount of income an individual would give up to make him indifferent between the original state: income at y and the public good at $\mathbf{q_0}$ and the revised state: income reduced to $y - WTP$ and the public good increased to $\mathbf{q_1}$. Contingent valuation is capable of obtaining the appropriate Hicksian measure for a proposed change in the public good (Mitchell and Carson 1989). It can be viewed as a way of estimating the change in the expenditure function (Haab and McConnell 2002). This study determines the value of groundwater conservation using the concept of WTP.

Methodology

Description of the study area

The study was conducted in Kombolcha district located about 514 kms south east of Addis Ababa. The district is having an area of 446.61 km^2, and found in the northern part of East Hararghe zone. The district falls under *Woina dega* (74%) and *Kola* (26%) agro-climatic zones. The annual rainfall and temperature of the district ranges from 600 mm to 900 mm and 18^{0}c to 23^{0}c, respectively. Based on the 2007 population and housing census of Ethiopia, the district has a total population of about 140,769 (FDREPCC, 2008). The livelihood of the population typically depends on crop-livestock mixed farming system. The district's farming economy is characterized by small and fragmented land holdings with an average of 0.25 hectare. The district is one of the major producers of vegetables including potato, onion, cabbage, beet root, tomato, and lettuce using irrigation water.

Sampling techniques and data collection methods

A two-stage sampling technique was used to select sample respondents. In the first stage, 3 rural kebeles were purposively selected out of the 19 kebeles based on identified as they are more attached to the water resource. These sample kebeles include Bilisumma, Kerensa and Walta Lamaan. In the second stage, proportionally with population percentage of these 3 kebeles, a total of 394 households were selected using simple random sampling techniques. Both secondary and primary data were used for this study. The primary data were collected using face to face interviews with the heads or working members of the households. A CVM method in the form of open ended elicitation format was used to elicit households' WTP for groundwater conservation.

Data analysis

The survey data was analyzed using descriptive statistics and econometric models. Tobit econometric model was used to analyze the determinants of WTP for groundwater conservation. This model has an advantage over other discrete choice models (Linear probability model, logistic, and probit) in that, it reveals both the probability and the maximum WTP of the respondents. In discrete choice models like probit and logit model the dependent variable ($\boldsymbol{y_i^*}$) is not observed, what we observe is the dummy variable. However, in Tobit model the dependent variable, or the WTP, is partially observed and the dependent variable ($\boldsymbol{y_i^*}$) assumes zero values for a substantial part of the sample. That is, $\boldsymbol{y_i^*}$ is observed if $\boldsymbol{y_i^* > 0}$ and is not observed if $\boldsymbol{y_i^* \leq 0}$. If y* and $\mathbf{x_i}$ were observed for everyone in the population, we could use standard regression methods (ordinary least squares (OLS)) (Maddala, 1992). However, in this study since we deal with maximum WTP for groundwater conservation which is partly observed, we employed Tobit model. The censored regression (Tobit) models generally apply when the variable to be explained is partly continuous. According to Maddala (1997) the equation for Tobit model is constructed as:

$$y_i^* = \beta x_i + \varepsilon_i \quad (3)$$

$$y_i = \begin{cases} y_i^* = \beta x_i + \varepsilon_i \text{ if } y_i^* > 0 \\ 0 \qquad\qquad\quad \text{if } y_i^* \leq 0 \end{cases}$$

where: y_i^* is latent or unobserved willingness to pay for groundwater conservation; y_i is a household's actual maximum willingness to pay; x_i is vector of explanatory variables; β is a parameter vector common to all households; α is the intercept; and assuming the random error ε_i is independent and normally distributed across respondents, $\varepsilon_i \sim NID(0, \sigma^2)$. Some of the households interviewed did not have any WTP, whereas, some of them had WTP for groundwater conservation. For those not undertaking WTP is zero in Tobit model the WTP is a random variable and has probability distribution, and it is possible to determine each observations probability.

$$p(y_i = 0) = p(\varepsilon_i < \beta x_i) = 1 - F(\beta x_i) \quad (4)$$

$$p(y_i > 0) = 1 - p(y_i = 0) = F(\beta x_i)$$

Where p is probability distribution and $F(\beta x_i)$ is cumulative density function

The model parameters can be estimated by maximizing the Tobit likelihood function of the following form.

$$L = \prod_{y^*>0} \frac{1}{\sigma} f \, In\left(\frac{y_i - \beta x}{\sigma}\right) \prod_{y^* \leq 0} \frac{1}{\sigma} F\left(\frac{-\beta x}{\sigma}\right) \quad (5)$$

f and F are the density probability function and cumulative distribution function of y_i^* respectively. $\prod_{y^*>0}$ means that the product over those i for which $y^* > 0$, and $\prod_{y^* \leq 0}$ means the product over those i for $y^* \leq 0$.

The Tobit coefficients do not directly give the marginal effects of the associated explanatory variable on the dependent variable. But their signs show the direction of change in probability of WTP as the respective explanatory variables changes. Therefore, it is not reasonable to interpret in the same way as the one interprets coefficients in an uncensored linear model (Johnston and Dinardo, 1997). Hence, we should estimate the marginal effect of the Tobit model. According to, Long (1997) and McDonald and Maffitt (1980) to identify the effects of explanatory variables on the probability of WTP, conditional and unconditional WTP the following techniques could be used.

The marginal effect of an explanatory variable on the expected value of the dependent variable was estimated by:

$$\frac{\partial E(y_i)}{\partial x_i} = F(z)\beta \quad (6)$$

The change in the probability of willingness to pay for groundwater conservation as explanatory variable X_i changes was estimated by:

$$\frac{\partial F(z)}{\partial X_i} = f(z)\frac{\beta}{\delta} \quad (7)$$

Similarly, the change in the probability of willingness to pay with respect to a change in explanatory variable among willing respondents was estimated by:

$$\frac{\partial E(y_i/y_i^*>0)}{\partial X_i} = \beta\left[1 - Z\frac{f(z)}{F(z)} - \left(\frac{f(z)}{F(z)}\right)^2\right] \quad (8)$$

Where, $z = \frac{X\beta}{\delta}$, *F(z)* is the cumulative normal distribution of Z, f(z) is the value of the derivative of the normal curve at a given point(that is, unit normal density), Z is the Z-score for the area under the normal curve, β is the vector of Tobit maximum likelihood estimates and δ is the standard error of the error term.

Result and Discussion

Characteristics of sampled households

A total of 394 sampled households were interviewed. However, 4 respondents were protested zero bidders and after checked for sample selection bias they were excluded from the data set. Of the total 390 respondents, 52% were males while 48% were female respondents. The age of these sampled respondents' ranges from 16 to 78 years with an average of 37.57 years old. The survey results also showed that 70% of the respondents were married and the rest 30% were single. A total number of 2552 persons were recorded with a minimum of 2 persons and a maximum of 12 persons per households. On average, about 7 persons per household were recorded which was above the national average of 4.7 persons (FDREPCC, 2008). This is because the households could have more than one wife. The result on the status of the respondents showed that 69% of the respondents were head of the households, and the rest 31% were working member of the households. Educational attainment is another parameter considered in our empirical models. The educational status of the sampled respondents ranges from zero (illiterate) to 10+3 years of schooling with an average of about 6 years of schooling. The total farm land holding of the sampled households was also estimated at 136.23 ha with average cultivated farm size per household of 0.35 ha (see Table 1). This indicated that the average farm size of the study area is lower than the national average of 0.8 ha (CSA, 1995).

Table 1. Socio-economic characteristics of the sample households

Variables	Mean	Std. Dev.	Min	Max
Maximum willingness to pay	60.63	42.80	0	200
Household income	1641.33	1342.40	258.33	5850

Age	37.57	15.60	16	78
Sex	0.521	0.50	0	1
Marital status	0.7	0.46	0	1
Educational level	5.89	3.54	0	13
Status of the respondents	0.69	0.46	0	1
Total family size	6.544	2.68	2	12
Tropical livestock unit(TLU)	1.86	0.70	1.56	3.87
Total farmland holding	0.349	0.27	0.2	1.83
Perception	0.815	0.39	0	1

Source: own survey, 2017

Major sources of income of the households' are from on farm activities primarily from production of crops and livestock production. The total monthly income of these households was computed at 495,117.56 ETB. On the other hand, the monthly income of the households obtained from off farm activities were also computed at ETB 145,000. The fact that off-farm incomes contribute smallest to the total family income, it explains that most of the surveyed household can rely mainly on agricultural activities with relatively narrow landholding size for their livelihood. Data related to livestock owned by the respondents was also collected in terms of TLU[3]. On average the survey result show that 1.86 TLU with a minimum of 1.56 and maximum of 3.87 was recorded per households (Table 1).

Causes and effects of groundwater degradation

The groundwater has been degraded to satisfy the demands of the ever increasing population for agricultural production. About 82% of the respondents were known the goods to be valued properly. They have an experience of using the resource for irrigation practices. The respondents reported that the availability of groundwater is decreasing from time to time. This shows that the depth of the water table is increase. The reasons attributed to the problem were population pressure, deforestation, soil degradation, agricultural expansion and climatic change. The result indicated that population pressure was the main causes of groundwater degradation. Therefore, the government should create awareness on family planning of the local people. On the other hand, about 18% of the respondents did not perceive the problems of groundwater degradation (Table 2).

Table 2. Causes of groundwater degradation

Causes	**Number of households**	**Percent**
Population pressure	82	21.03
Deforestation	60	15.38
Soil degradations	78	20
Agricultural expansion	65	16.67

3 Conversion factors used in estimation of tropical livestock unit (TLU) were Donkey = 0.7; Cow, Bulls and Ox=1; Calf = 0.25; Sheep and Goats= 0.13; Chicken=0.013 and Camel = 1.25

Causes	Number of households	Percent
Climate change	35	8.97
None	70	17.95
Total	390	100

Source: Survey result, 2017

They pay nothing for the water resource except the withdrawal and digging cost. This is because the wells used for irrigation practices is owned as private property. They bought motor pump on average estimated at birr 9000. The fuel used to pump the water was 1.5 liter per hour. The survey result shows that the price of the fuel at the time of the survey was 25 birr per liter. The price of the fuel is above the price set by the Ethiopian government, and its shows that there was a black market.

Seven effects of groundwater degradation perceived by the respondents were also identified and described: (1) health problem (2) delay in household chores (3) food shortage (4) low income, and (5) enhanced climate change. In particular, 19.23% of the respondents indicated that health problem was the effects of groundwater degradation. About 20.51% of the respondents' reported that they earned low income (Table 3).

Table 3. Effects of groundwater degradation

Effects	Number of households	Percent
Health problem	75	19.23
Delay in household chores	60	15.38
Food shortage	78	20.00
Low income	80	20.51
Enhanced climate change	27	6.92
None	70	17.95
Total	390	100

Source: Survey result, 2017

Protection measures were also elicited from the aware respondents for possible improvement of the degraded groundwater. A majority of the respondents suggested that strong government regulation, soil and water conservation, tree planting and training groundwater users are among the protection measures (Table 4).

Table 4. Perception on protection measures of groundwater degradation

Protection measures	Number of households	Percent
Strong government regulation	58	14.87
Soil and water conservation	87	22.31
Tree planting	95	24.36
Training groundwater users	80	20.51
None	70	17.95
Total	390	100

Source: Survey result, 2017

Households WTP for groundwater conservation

The result shows that 75.38% of the sampled households were willing to pay for groundwater conservation. Using open ended elicitation format the mean WTP were estimated at 60.63 ETB per year per household for ten years. The willing respondents were also asked to point out their reasons for maximum WTP in ETB. The respondents provided different reasons for their maximum WTP. About 48.97% of the respondents reported that they could not afford more than what they stated because of inadequate income. While, 13.33% and 13.08% reported that the amount they decided to pay was satisfactory, and other should pay respectively. However, about 24.62% of the sample respondents' were not willing to pay for groundwater conservation.

Factors affecting households' WTP

Estimate of the parameters of the variables expected to affect willingness to pay for groundwater conservation are shown in Table 5. The dependent variable is partly a continuous variable that individuals respond as maximum willingness and ability to pay for the improvement service recalling the benefits expected out of it. A total of 10 explanatory variables were considered in the econometric analysis, out of which 6 explanatory variables were statistically significant. The other 4 explanatory variables are insignificant effect on the amount of WTP for groundwater conservation.

Table 5. The Tobit model estimation results of households' WTP

Dependent variable: Maximum Willingness to Pay; 390 observations			
Explanatory Variables	Coef.	Std.Err.	t-value
Households income	0.008***	0.002	3.87
Age	-0.235	0.204	-1.15
Sex	-0.53	5.65	-0.09
Marital status	2.927	8.04	0.36
Education	2.213***	0.801	2.76
Respondents status	0.308	8.07	0.04
Total family size	2.412**	1.08	2.23
Tropical livestock unit	11.56***	3.97	2.91
Total farm land holding	20.43**	9.74	2.1
Perception	6.61**	6.98	0.95
_Cons	-5.17	16.45	-0.31
Log likelihood = -1676.30			
LR chi2(10) = 40.87			
Prob > chi2 = 0.000			
Obs. summary: 96 left censored observations at maxwtp<=0;			
294 uncensored observations			
0 right-censored observations			

*** significant at 5%; *** significant at 1% significance levels (survey result, 2017)*

However, the interpretation of the censored regression model is not straightforward. That is, the marginal effects cannot be adequately explained from the estimated coefficients

of the Tobit model. Therefore, for interpretation of the Tobit model this paper report three sets of marginal effects: (1) the effect on the probability of a positive WTP, (2) the effect on conditional WTP, and (3) the effect on unconditional WTP for groundwater conservation. To be more specific, households' monthly incomes have positive and significant association with the households WTP for groundwater conservation. That is, when the income of the household increase by one birr, it would increase the probability of willingness of a household to pay by about 0.004%. Besides, when income of the household increase by one birr their willingness to pay would increase, on average, by about 0.007 ETB for all observation and 0.005 ETB for willing respondents', *ceteris paribus*. This shows that groundwater resource is a normal economic good whose demand changes in the direction of income change. Respondents with higher education levels were more likely to state positive WTP, and on average, they actually stated higher conditional and unconditional WTP than respondents with lower educational levels. This result suggests that investing in education of people might help to improve the degraded environmental resource like groundwater. The marginal effect of the result shows that the respondent being educated, the probability of willingness to pay increases by 0.2%. Also, as the years of education increases by one year, the amount of cash the household is willing to pay for groundwater conservation increase by 1.88 birr for the whole sample of study, and 1.41 birr for the willing respondents, *ceteris paribus*. The variables perception has positive and significant effect on the amount of WTP. A unit changes in perception from 0(unperceived) to 1 (perceived) the probability being willing to pay increases by 2.86%. That is, the marginal effect result shows that a unit changes from 0 to 1 the willingness to pay increased by 5.67 birr and 4.3 birr for the whole and willing respondents respectively, *ceteris paribus* (Table 6*)*.

Table 6. Marginal effects of the explanatory variable on the amount of willingness to pay

Explanatory Variables	Change in probabilities as explanatory variable changes	Change among individuals who are willing to pay	Change among the whole
Households income	0.00004	0.005	0.0069
Age	-0.00106	-0.15	-0.1994
Sex	-0.00239	-0.339	-0.4499
Marital status	0.01338	1.86	2.478
Education	0.00199	1.41	1.879
Respondents status	0.00139	0.197	0.2611
Total family size	0.0109	1.54	2.048
Tropical livestock unit	0.0522	7.39	9.814
Total farm land holding	0.0923	13.06	17.34
Perception	0.0286	4.3	5.671

Source: own survey, 2017

Aggregate WTP for groundwater conservation

An important issue related to the measurement of welfare using WTP is aggregation of benefit (Alemu, 2000). According to Mitchell and Carson (1989) there are four important

issues to be considered regarding sample design and estimating a valid aggregation of benefits: population choice bias, sampling frame bias, none response bias and sample selection bias. Random sampling method was used in this study using a list of households. Face to face interview methods was used and protest zero responses were excluded from the analysis and expected protest zeros was accounted in the estimation of the total aggregate benefit of groundwater conservation in this paper. Hence, none of the above biases was expected in this study. Mean WTP was used as a measure of aggregate value of groundwater conservation in this study. The mean is perhaps better than the median since the good dealt with is not a pure public good (Alemu, 2000), as there are purely private benefits from groundwater conservation measures. As it is indicated in Table 7 below, the aggregate WTP was calculated by multiplying the mean WTP by the total number of households in the population. Following this, the aggregate WTP for groundwater conservation was computed at 1,689,576.21 birr per year for ten years.

Table 7. Aggregate Benefits of groundwater conservation

Total households (Y)	Expected households to have a protest zeros (X)[4]	Expected households with valid responses (Z)[5]	Mean WTP[6]	Aggregate Benefit (in Birr)[7]
28154	287	27867	60.63	1,689,576.21

Source: Own survey, 2017

Conclusion and Recommendations

The purpose of this study was to assess the economic value of groundwater conservation using CVM. The descriptive analysis shows that 82% of the respondents reported that the availability of groundwater is decreasing from time to time, and the reasons attributed to the problem were population pressure, deforestation, soil degradation and agricultural expansion and climatic change. In order to improve the availability of groundwater policy makers should encourage and provide technical advice to households who are planting and maintaining tree resource, and practicing soil and water conservation. The results of the study on willingness to pay showed that the households were willing to pay for groundwater conservation. The annual mean WTP value of households was computed at 60.63 birr per year. Small respondents were recorded as protest zero, and imply that contingent valuation method is appropriate method to value groundwater

4 4(1.02%) of 394 sampled households were protest zeros. We excluded those protest zeros from further analysis after we have tested for sample selection bias. So X is the expected number of households which are expected to protest for the proposed project. It is calculated by the percentage of sampled protest zeros (1.02%) by the total population 28154 (Y).

5 Y-X is the total households in the study area which are expected to have a valid response

6 Is the mean willingness to pay calculated from the open ended elicitation methods

7 Is mean multiplied by the number of total households which are expected to have valid response (Z*Mean WTP) measured in ETB

conservation. Thus, in estimating the value of environmental resource at household level, it is important to use contingent valuation method. The empirical findings on the determinants of WTP indicated that monthly income, educational level, total farm land holding, total family size, tropical livestock are key factors influencing the willingness to pay. Besides, the study estimated that there is a statistically significant and quantitatively non-negligible effect of perception on the households' WTP. Generally, the study leads us to conclude that understanding of socio-economic characteristics that significantly influenced households WTP is a necessary and first step to achieve groundwater conservation. Therefore, when designing groundwater project any policy maker should consider significant socio-economic factors for successful groundwater project at household level.

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CONTENT