Households' Willingness to Pay for Water Hyacinth Control in Lake Tana

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Abstract

This study analysed rural households' WTP for control of water hyacinth (Eichhornia crassipes) infestation in Lake Tana in terms of cash and man-days. A contingent valuation method through double bounded dichotomous choice was used to elicit WTP of 276 households in Fogera district, western Ethiopia. It was found that initial bid price, age of household head, labour availability, trust in the government, place of residence, household size, and income to influence the probability of households WTP for control of water hyacinth. The mean WTP was estimated to be 26.41 ETB and 3.23 man-days per month per household with welfare aggregation of ETB 19,671,963 *and 2,404,441 man-days per year. The study underscores that in utilizing the public resource for water hyacinth control activities, accountability and transparency should be strengthened.*

Keywords: Lake Tana, Man-days, Labour contribution, Water Hyacinth control, Contingent valuation method
JEL Classification: Q51

1. Background

The environment has a remarkable value to humanity, from the natural resources that give the basic inputs for the economy to the ecological services (Haris, 2006). Lakes and rivers are some of the environmental goods and they are the most available water resources for human utilization and for maintaining the

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balance of the whole ecosystem (Rientjes et al., 2011). Lake Tana is the largest freshwater resource in Ethiopia and is the third largest lake in the Nile Basin countries. Over half a million people directly or indirectly dependent on the lake and its wetlands (Vijverberg et al., 2009). It renders essential services for the riparian societies as a source of water for drinking, cattle watering, irrigation, recreation, and transportation service that links islands and lake shore towns (Goshu & Aynalem, 2017). Generally, the lake is an essential environmental good that has economic, social, political, religious, and ecological benefits.

It is the source of the Blue Nile River, a huge habitat for diverse species of birds and fishes (Aynalem & Bekele, 2011; Nagelkerke et al., 1995; Shiferaw & Yazezew, 2021; zur Heide, 2012). Asmare (2017) claims that there are 10 prospective fishing districts in which more than 5400 fishermen work both full- and part-seasons to support their families. Additionally, a significant portion of low-income households depend primarily on the lake's fish supply, while other households turn to wetland farming as a secondary source of income.

The lake region with over 37 islands is a UNESCO's biosphere reserve which has high tourist attractions in Ethiopia (Danbara, 2014; Goshu & Aynalem, 2017). Moreover, the wetlands of the lake have socio-economic and ecological benefits such as food and water supply, provision of construction materials, erosion regulation, water purification and storage, habitat for birds and pollinators, flood control, and climate regulation (zur Heide, 2012). The lake supplies irrigation water for the country's largest rice production region (Vijverberg et al., 2009). The water hyacinth (Eichhornia crassipes) is currently a significant issue in Lake Tana (Firehun, 2017; Van Oijstaeijen et al., 2020). The infestation is a current occurrence that has rapidly expanded throughout several parts of the lake's shorelines (Fahser et al., 2015). The dense carpets of water hyacinth disrupt economic activities and negatively influence the indigenous aquatic biodiversity since they block sunlight from reaching the aquatic ecosystem (Gichuki et al., 2012). It also disrupts transportation and seriously affects urban and industrial water supply and irrigation through clogging pipes and canals (Patel, 2012).

The assessment of water hyacinth coverage conducted in August 2017 revealed 5,396 ha of land coverage, of which 481 ha of water were covered only in the two communes of the Fogera district, Nabega and Wagetera (Environment, Forest, and Wild Life Protection and Development Authority, 2018). Besides, the weed can grow throughout the entire year in the tropical and subtropical climate zones, and its seed can stay viable for up to 28 years (Shaohua Yan & Jun Yao Guo, 2017).

The infestation of freshwater bodies with the weed poses different problems for many human uses (Kateregga & Sterner, 2009). Once established, it is extremely difficult to eradicate because of its fast growth rate in which its size of infestation can double as little as in 8 days at favourable circumstances (Australian Weeds committee, 2012; Villamagna & Murphy, 2010).

Additionally, it affects hydro-power operations, tourism and its dense mats influence fish production by either diminishing fish population or obstructing the way to fishing grounds (Shaohua Yan & Jun Yao Guo, 2017). Nowadays, in the north-eastern part of Lake Tana, particularly, around the shore areas, fishing has become tiresome as a consequence of this invasive weed. Since the weed expansion hinders fishing activities, for instance, fishers in Nabega village in Fogera district shift their landing site to the nearby district of Libokemkem (Asmare, 2017). The weed also creates favourable growth condition for mosquitoes, and snail species known to host a parasitic flatworm which causes bilharzia (zur Heide, 2012).

Consequently, in the efforts of water hyacinth control in Lake Tana, health problems such as threats of bilharzia, leech bites, and malaria were observed (Edward R., 2013). It also created an extra burden on the inadequate health services and facilities available to the rural communities in least-developed countries like Ethiopia (Firehun, 2017). Furthermore, if a well-designed and organized preventive strategy is not followed, the expansion of water hyacinth could endanger the sustainability of Lake Tana (Asmare, 2017). The infestation also results in high wastage of water through evapotranspiration, which can be up to three times greater than the normal evaporation of open water (Sasaqi et al., 2019).

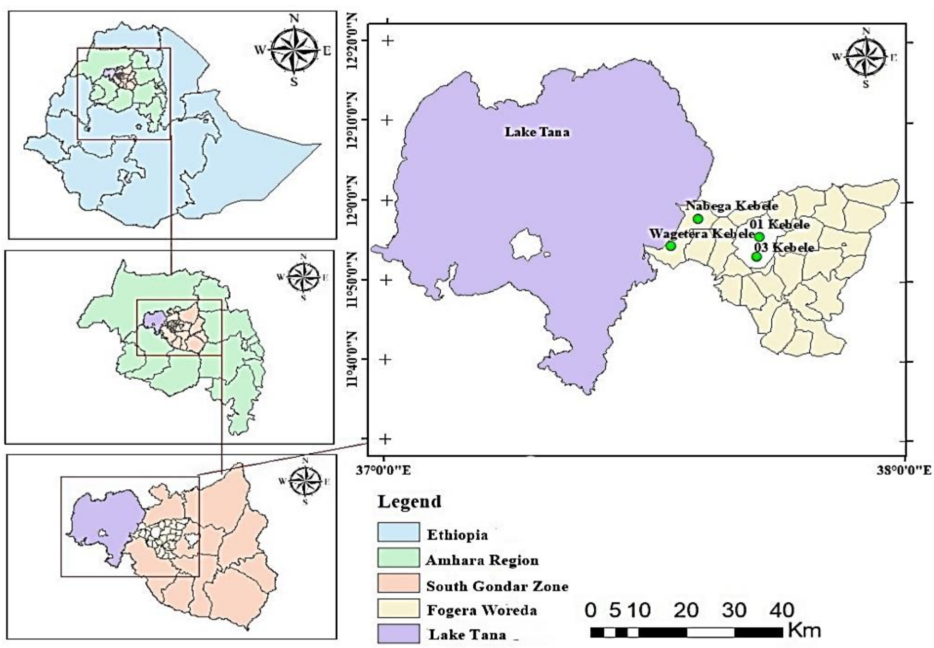
The manual removal of water hyacinth is one of the most efficient weed control methods. . However, using labor to control the weed requires careful planning and sustained effort (Australian Weeds Committee, 2012). Wassie et al. (2015) suggested that a significant amount of public resources, including money and labor, are needed to manage the weed in Lake Tana. Once during the first year of the study, district officials conducted a water hyacinth clearing effort. During the course of the operation, it was discovered that removing the weed from the lake in a single campaign was difficult due to its quick development and spread. Yet, good coordination of the utilization of the available resources, such as money and manpower, by the locals is necessary if the weed is to be properly controlled for a longer period. Through the purchase of additional weed harvesters, the hiring of additional experts to manage the weed, and the hiring of full-time workers to physically remove the weed, the creation of public awareness about the dangers of water hyacinth using various media, labour and financial resources can contribute to improving water hyacinth removal. Yet, prior actions taken by the local administration apparently failed to consider how willing the local people were to contribute time, labour and money to the weed eradication effort. Therefore, this study aims to identify determinants that influence households' willingness to pay (WTP) for the intervention and to estimate the mean monthly amount of cash and man-days they are willing to pay or contribute for the control of water hyacinth weed on Lake Tana.

2. Methodology

2.1. Description of the study area

The study was conducted in Fogera district, in the South Gondar administrative zone of the Amhara National Regional State of Ethiopia (Figure 1). The district comprises a huge portion of the Lake Tana and Fogera floodplain. The floodplains is an important international ecological resource recognized by the Important Bird Areas (IBAs) for its support of globally threatened bird species (zur Heide, 2012). According to the report of the Amhara Region Environment, Forest, and Wild Life Protection and Development Authority (2018), the district is one of the six water hyacinth-infested districts where the two sample *kebeles*, namely *Wagetera* and *Nabega*, are located.

Figure 1: Map of the study area



2.2. Data source and sampling

Primarily, the data used in this study were collected using face-to-face interviews, focus group discussions (FGD), and key informant interviews. The face-to-face interview was conducted using structured questionnaire. The survey questionnaire was pre-tested on a few pilot households. Then, the final survey was administered on January 2018. A secondary set of data, obtained from the Fogera Woreda Office of Agriculture (FWOA) and the Woreta town administrative office, was also used to complement the primary data.

Sample households were drawn using a two-stage sampling technique. In the first stage, two *kebeles*, namely, Wagetera and Nabega *kebeles*, were selected from a total of 33 rural *kebeles* of Fogera district purposively for their larger water hyacinth coverage. Moreover, two additional *kebeles* (01 and 03) were selected from four *kebeles* of Woreta town, which is the capital of the district, randomly. In total, the study covers two *kebeles* from the rural population and two from the urban community. In the second stage, a simple random sampling technique was utilized to draw representative households.

The study used 276 representative samples from 62,293 total households of Fogera district including Woreta town. Sample size was determined using Yemane formula (1967) With a 95% confidence level and ± 6% margin of error, the sample size was determined as follows:

$$n = \frac{N}{1 + N(e^2)} = \frac{62{,}293}{1 + 62{,}293(0.06^2)} = 276.54 \approx 276 \;---(1)$$

Where n= Sample size, N= total household, e = the sampling error or the level of precision (0.06).

Table 1: Proportion of sampled households in the sampled kebeles

Sampled kebeles	Total household size	Sampled households
Nabega	2,246	67
Wagetera	2,871	53
01 kebele	4,773	110
03 kebele	1,970	46
Total	**11,860**	**276**

Source: Survey data, 2019

Three FGDs were conducted in December 2018. FGD 1 was conducted in Wagetera kebele with 15 individuals including 2 district leaders and one kebele leader, FGD 2 was conducted in Nabega kebele with 10 individuals, and FGD 3 was held in 01 kebele with 11 individuals from different age, sex, and literacy groups. Besides, five key-informant interviews were also conducted. The key informant interview was conducted to get in-depth information regarding the water hyacinth removal efforts, experience, and problems caused by the weed expansion. The participants were selected in collaboration with Fogera district office of Agriculture, Water hyacinth control wing of the Amhara region Environment, Forest and Wild Life Protection and Development Authority, and development agents in Nabega and Wagetera *kebeles*. The main survey was conducted from January 02, 2019 to January 27, 2019.

Furthermore, a pilot survey was conducted on 17 randomly selected households to develop a hypothetical market scenario for the contingent valuation method (CVM). Following the survey, three initial bid values for both payment methods (cash and man-days) were identified as ETB 10, 20, and 30 per month, and 2, 4, and 6 man-days per month to be extended for two consecutive years. These initial bid values were equally distributed among the questionnaires. Then, the questionnaires were randomly distributed among the respondents. This will allow the researchers to trace out the distribution of WTP for the proposed project (Carson, 2000).

The elicitation of the WTP for controlling water hyacinth in two consecutive years for this proposed project was initially adapted from the five-years (2012-2015) management plan of the Lake Tana Biosphere Reserve (Fahser et al., 2015). In this plan, the scheme of removing of water hyacinth was planned to be applied for two consecutive years. Moreover, before adopting it for this study, it was discussed with FGDs and pretested to check its relevance.

2.3. Estimation strategy

Recently, households' WTP for water hyacinth control was investigated by Tasew (2019) on Lake Tana, Ethiopia, and John et al. (2019) on Lake Victoria, Kenya. These studies mainly examined the WTP in terms of money but not labour. However, rural households are highly cash-constrained decision-making units with regard to nature conservation (M. Tilahun et al., 2015). Unlike most related preference valuation studies, which were conducted either using monetary payment (Berhan.Asmamaw et al., 2017; John et al., 2019; Mezgebo et al., 2013;

Tasew, 2019) or labour contribution (Asmamaw et al., 2016; Belay, 2018), this study used both cash and labour contribution as payment vehicles to elicit households' WTP. The reason to use labour contribution as an alternative payment method is to address the issue of cash scarcity in the study area context, which may mislead the study result to an underestimation of its value. The addition especially provides more flexibility to the resource exchange scenario in cash-scarce rural contexts, as suggested in the study (Gibson et al., 2016; Schiappacasse et al., 2013). Besides, the study used urban and rural households together to examine their preferred mode of payment for the proposed water hyacinth control strategies. As suggested by Tasew (2019), about 98% of the households near Lake Tana had positive WTP for water hyacinth control. Similarly, a CV study by John et al. (2019) estimated the willingness to pay of Fisher Folks' in Lake Victoria, Kenya found out that a mean WTP of US$1.75 per month was needed for the improved management of water hyacinth. The study also indicated that income, sex, and perceptions about water hyacinth infestations had a positive influence on maximum WTP, whereas age, experience, distance from the place of residence to the nearest fishing ground, and membership in a fishing group had a negative influence on WTP of the Fisher folks.

Use and non-use values of ecosystem services can be measured using conjoint, choice experiments, and contingent valuation methods (CVM) (Loomis et al., 2000). However, CVM was used in this study as it is the most widely used valuation technique and has the ability to estimate total values by directly asking the respondents about the value of the good to be used for economic analysis (Carson, 2000; Van Oijstaeijen et al., 2020). It is called “contingent” since individuals are asked to state their WTP contingent on a hypothetical scenario presented in a survey (Anderson, 2013). This method requires respondents to directly state their WTP for non-use values rather than infer them from observed behaviours in regular marketplaces (FAO, 2000).

According to Barry (2016), the basic steps in a CVM are: identification and description of the environmental quality characteristics or change, identification of sample respondents; design and application of a survey questionnaire; and investigation of results and aggregation of individual responses to estimate values for the group affected by the environmental change. Following this, we developed a double-bounded elicitation question format followed by an open-ended question to elicit the WTP of respondents. The repeated question that comes from this method increases the efficiency of WTP elicitation (Hoyos & Mariel, 2010). According to Haab and McConnell (2002), the double-bounded format is statistically more efficient than the single bounded format for three reasons. Firstly, the number of responses increases due to repeated questions. Secondly, it is used to constrain the distribution of WTP even when it does not bind it completely (in the case of Yes-Yes or No-No). Finally, in the case of Yes-No or No-Yes responses, there is a clear bound in WTP responses.

The double-bounded questions were asked to the respondents, starting with asking whether they would be willing to pay an initially offered bid amount, requiring a "yes" or "no" response. If the response was "yes" for the first offered bid, then the respondent will be asked if he or she will be willing to pay for a higher amount (the initial bid plus its half); but if the response is "no" for the first offered bid, then the respondent will be asked if s/he will be willing to pay for a lower value (half of the initial bid value). After these double-bound questions, an open-ended question was followed to capture respondents' maximum WTP in cash and man-days for the proposed project. This elicitation method is similar to the real market situation in Ethiopia, where buyers and sellers negotiate with each other on the price of a given good. The open-ended WTP question was used to elicit the maximum amount of cash and man-days they would like to pay for control of the water hyacinth weed infestation on Lake Tana. The result from this format was used for two purposes: (i) to compare the mean WTP with the result of the dichotomous choice elicitation format and (ii) to sketch the aggregate demand curve for the proposed hypothetical program. The dummy results from the first bid will be used to identify the determinants of households' willingness to participate in the proposed project.

A probit model was used to identify factors that affect households' WTP in terms of monetary payments and labour contributions. Assuming a normal distribution of the error term, following Hanemann (1984), the probit model can be specified as follows:

$$y^* = x{\cdot}\beta + \in_i \qquad \textbf{(2)}$$

$$Y_i = 1 \; if \; Y^* \geq t_i^* \qquad \textbf{(3)}$$

$$Y_i = 0 \; if \; Y^* < t_i^* \qquad \textbf{(4)}$$

Where: Y^* = unobservable (for the researchers) households' actual WTP for the proposed project. It is simply a latent variable, β' = a vector of unknown parameters of the model, x_i = is a vector of explanatory variables, Y_i = discrete response of the households for WTP, t_i^* = the offered initial bids assigned arbitrarily to the i[th] respondent, ε_i = unobservable random component of the model which is normally distributed.

To estimate the mean WTP from the double-bound dichotomous elicitation method, the bivariate probit model was used for WTP in cash and labour. Following Greene (2012), a bivariate probit model can be specified as follows:

$$y_1^* = \beta_1 x_1 + \varepsilon_1 \quad \textbf{(5)}$$

$$y_2^* = \beta_2 x_2 + \varepsilon_2 \quad \textbf{(6)}$$

$$E\ (\varepsilon_1 | x_1, x_2) = E(\varepsilon_2 | x_1, x_2) = 0 \quad \textbf{(7)}$$

$$Var\ (\varepsilon_1 | x_1, x_2) = Var\ (\varepsilon_2 | x_1, x_2) = 1 \quad \textbf{(8)}$$

$$Cov\ (\varepsilon_1, \varepsilon_2 | x_1, x_2) = \rho \quad \textbf{(9)}$$

Where, y_1^*= i^{th} respondent unobservable true WTP at the first pre-specified bid; y_2^* = i^{th} respondent unobservable true WTP at the second pre-specified bid ; $x_1\ and\ x_2$ are the first and second bids offered to the respondents, respectively; $\varepsilon_1 and\ \varepsilon_2$ are the error terms that are identically and independently distributed random variables with zero mean; β_1 and β_2 are coefficients of the first and second bids offered, respectively and ρ (Rho) is the correlation coefficient, which is the covariance between the errors for the two WTP functions.

The mean WTP was estimated using the formula specified by Haab & McConnell (2002)

$$WTP = -\frac{\alpha}{\beta} \quad \textbf{(10)}$$

Where α = a coefficient for the constant (intercept) term, β = the coefficient of the 'bid' value posed to the respondent in the bivariate probit regression model. When the estimated correlation coefficients of the error terms in the bivariate probit model are assumed to follow normal distributions with a zero mean and are distinguishable from zero, the system of equations could be estimated as a seemingly unrelated bivariate probit (SUBVP) model. Therefore, in this study, we employed SUBVP to estimate the mean WTP of sampled respondents. For the open-ended CV survey data, the mean WTP can be calculated simply by averaging the maximum WTP amounts stated by the individual households for both cash and man-days. Moreover, data from this survey could possibly be used to draw the aggregate demand curve or latent demand curve by inferring households' WTP for the proposed project (Hanemann, 2018).

3. Results and Discussion

3.1. Description of responses

Before the WTP elicitation questions, individuals were asked if they would pay or contribute any amount of cash or number of man-days for the proposed project. Thus, yes-no questions were designed to assess the WTP status of the respondents in terms of cash and man-days. Based on the survey data, out of the total 276 randomly selected households, about 99.64% (275) of the respondents were willing to pay in terms of cash, labour-days and/or awareness creation (about the problem of water hyacinth and the benefit of environmental conservation). Thus, from a total of 275 willing households, 222 (about 81%) of respondents were willing to pay in terms of cash, 178 (about 65%) were willing to participate in terms of days of labour, and 96 (about 35%) households were willing to participate in terms of awareness creation (Table 2 and Figure 2).

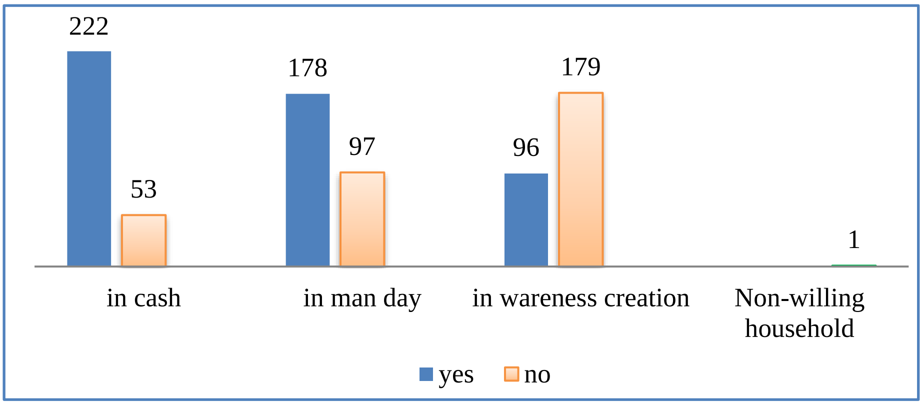
Table 2: Respondent's distribution in terms of their WTP status

Modes of participation for willing Households	Proportion of willing (%)
Money only	28.3
Money and Labor	18.8
Money and Awareness creation	6.9
Money + Labor + Awareness creation	26.5
Labor only	17.7
Labor and Awareness creation	1.4
Total	99.6
Non-willing to pay	0.4
Total	100

Source: Survey data, (2019)

Households were also categorized based on their joint responses to the initial and follow-up offered bids (the response to the three randomly distributed bid sets). Out of the total 275 respondents, 44% of households accepted both the initial offered bid and the increased follow-up bids (yes-yes) for WTP in cash, whereas about 26% of households accepted both bids (yes/yes) in man-days contribution. The percentage of households that accepted the initial bid but not an increased follow-up bid (yes/no) was found to be about 25% for WTP in cash and 21% for WTP in man-days contribution. The percentage of households that rejected the initial bid but accepted a decreased follow-up bid (no-yes) was found to be 12% for WTP in cash and 17% for WTP in man-days contribution. The last category in which respondents rejected both the initial bid and the discounted follow-up bid (no-no) accounts for 19% of the households for WTP in cash and 36% of the households for WTP in man-days contribution.

Figure 2: Respondent's distribution summary in terms of their WTP status



Source: Survey data, 2019

As a response to a separate question to identify the reasons for the refusal, 19% in the monetary case and 36% in the labour case responded that they had a low level of income and could not pay for the proposed project. As a result, they were categorized as genuine zeros.

3.2. Willingness to pay

Based on the formula specified by Haab and McConnell (2002), the mean WTP in cash for the removal of water hyacinth from Lake Tana was estimated to be ETB 26.41 per month per household to be extended for two consecutive years, with a range of ETB 25.03 to ETB 27.79 at a 95% confidence interval based on the result of a seemingly unrelated bivariate probit model (Table 3). In other words, the average respondent would be willing to pay ETB 26.41 per month of their total annual household income to support this proposed project.

Table 3: Seemingly unrelated bivariate probit model estimation for mean WTP in cash

Variables	Coefficient	Standard Error
Initial Bid (BID1)	-0.076***	0.011
Constant	2.100***	0.266
Second Bid (BID2)	-0.026***	0.006
Constant	0.651***	0.146
Rho	0.376	0.102
No. of observations	275	
Log- likelihood=-318.502	Likelihood-ratio test of rho=0:	
Wald chi2(2)=58.60	chi2(1) = 11.552	
Prob> chi2=0.0000	Prob > chi2 = 0.0007	

*** Represents statistical significant at 1% (Source: Survey data, 2019)

In the labour contribution case, the estimated mean WTP in man-days for control of water hyacinth weed infestation on Lake Tana was estimated to be 3.23 man-days per month per household, to be extended for two consecutive years. At a 95% confidence interval, the mean WTP for this proposed project varies from 2.93 to 3.52 man-days per month per household based on the result of a seemingly unrelated bivariate probit model (Table 4). That is, the average respondent would be willing to pay 3.23 man-days per month from their total annual working labour-days to support the proposed project.

Table 4: Seemingly unrelated bivariate probit model estimation for mean WTP in man-days

Variables	Coefficient	Standard Error
Initial Bid (l_Bid1)	-0.192***	0.044
Constant	0.678***	0.187
Second Bid (l_Bid2)	-0.205***	0.038
Constant	0.601***	0.163
Rho	0.692	0.100
No. of observations	275	
Log- likelihood= -351.938	Likelihood-ratio test of rho=0:	
Wald chi2(2)= 41.86	chi2(1) = 24.620	
Prob> chi2= 0.0000	Prob > chi2 = 0.0000	

*** Represents statistical significant at 1% (Source: Survey data, 2019)

3.3. Aggregate revenue and demand

The estimated mean WTP from money and labour contributions was used to estimate the aggregate benefits of this proposed project. The mean WTP was multiplied by the total number of households expected to have valid WTP responses in the aggregation of WTP for the sampled households and the total population of the study area. In other words, the proportion of the protest zero was omitted in the calculation of total WTP. Thus, the calculated total WTP amount from sampled households for each sampled *kebeles* of the study area is presented in Table 5. Thus, the total WTP for the four sampled *kebeles* was estimated to be ETB 3,745,365 per year and 457,784 man-days per year, which is equivalent to ETB 27,467,045[4] per year.

[4] It was calculated by multiplying the total WTP in man-days with the current minimum wage rate (ETB 60) in the study area at the time of data collection. In this study, all of man-days contribution was converted to ETB by using this wage rate.

Table 5: WTP aggregation in cash and man-days for sampled households by kebeles

Payment Mode	Kebeles	Total HHs	Expected HHs to have a protest zero[1]	Expected HHs with valid responses[2]	Mean WTP per month	Mean WTP per year	Aggregate benefit per year
Cash	Wagetera	2,246	8	2,238	26	316.94	709,327
	Nabega	2,871	11	2,860	26	316.94	906,469
	Keb. 01	4,773	17	4,756	26	316.94	1,507,400
	Keb. 03	1,970	7	1,963	26	316.94	622,167
	Total	11,860	43	11,817			3,745,365
Labor	Wagetera	2,246	8	2,238	3	38	86,698
	Nabega	2,871	11	2,860	3	38	110,794
	Keb. 01	4,773	17	4,756	3	38	184,244
	Keb. 03	1,970	7	1,963	3	38	76,045
	Total	11,860	43	11,817			457,784

Source: Survey data, 2019

[1] The proportion of a protest bidder in the sample (1/276 household in this study) times the total population of each sampled kebeles. For example, (1/276)*2,246=8 expected protest bidders in *Nabega kebele*.
[2] The total households of each kebeles minus the corresponding number of expected protest bidders.

Moreover, as shown in Table 6, extrapolating the estimated mean value to the whole households in the study area, aggregate WTP was estimated to be ETB 19,671,963 per year and 2,404,441 man-days per year, which is equivalent to ETB 144,266,489 per year.

Table 6: WTP aggregation in cash and man-days from close ended questionnaire format

		Modes of payment	
		Cash	**Labor**
Total HHs	62,293		
Expected HHs to have a protest zero[1]	226		
Expected HHs with valid Responses[2]	62,067		
Mean WTP per month		26.41	3.23
Mean WTP per year		316.94	38.74
Aggregate benefit per year		19,671,963	2,404,441

Source: Survey data, 2019

Besides, for comparison purposes, the aggregate benefits were also computed from the open-ended CV data. The result demonstrated that the amount of cash that the households would contribute for the proposed project ranges from 0 to 100 ETB per month per household, to be extended for two consecutive years. In the case of labour contribution, the number of man-days that the households would contribute to the proposed project ranges from 0 to 10 person-days per month per household, to be extended for two consecutive years. The average amount of money that respondents were willing to pay in the open-ended WTP format was estimated to be ETB 19.24 per household per month. On the other hand, the mean WTP in man-days was 2.89 per month per household.

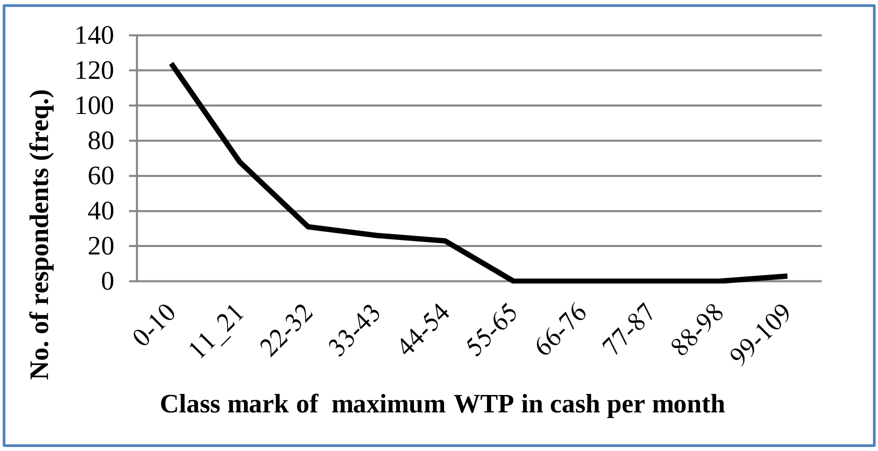
According to Cameron et al. (2002), the result from dichotomous choice methods produces estimates that tend to be larger, and the WTP ratio between dichotomous choice and open-ended methods generally seems to range between 1.1 and 5, even if there are some exceptions. Thus, from this study, we can notice that the WTP amount from the result of the dichotomous choice method was larger than the WTP amount from the result of the open-ended method in both

[1] The proportion of a protest bidder times the total population (1/276)*62,293 =275.699≈276
[2] 62,293-276 = 62,067

payment mechanisms. This might be due to the human beings free-riding behaviour, enjoying the benefits of conservation activities at the expense of others. Moreover, the mean WTP ratios between dichotomous choice and open-ended formats were 1.37 and 1.12 for the WTP in cash and the WTP in man-days, respectively.

The open-ended CV data were used to estimate the latent aggregate demand curve for the proposed project in Figures 3 and 4 for cash payment and labour contribution, respectively. In the two figures, the frequency curve measures the total number of households along the vertical axis and the amount of birr, or number of man-days per month, stated by the households along the horizontal axis.

Figure 3: The frequency curve from elicited maximum WTP in cash

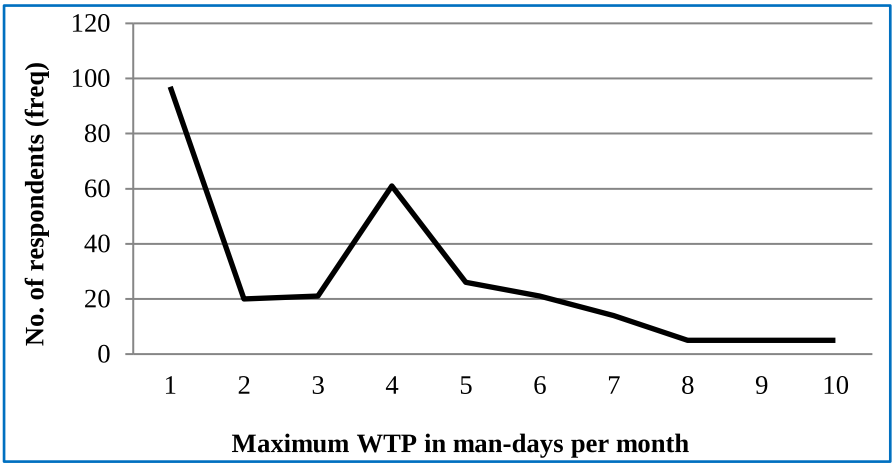


Source: Survey data, 2019

Nevertheless, the demand curves sketched from this study did not look like the usual aggregate demand curve since WTP responses are likely to vary depending on an individual's characteristics. However, in the case of marketable goods, the price of the good is equal to its marginal value, which is consistent across individual characteristics. In figures, the fitted linear trend line shows that, on average, the proportion of respondents gets lower when the bid amount in both cash and man-days gets higher which conforms to the law of demand.

From the open-ended data format, the total perceived welfare benefit in cash for the proposed project of the total population of the study area was computed to be ETB 1,122,171 per month and ETB 13,466,056 per year. On the other hand, the aggregate WTP in man-days for this proposed project for the total population of the study area was computed to be 109,689 man-days (ETB 6,581,359) per month and 1,316,271 man-days (ETB 78,976,307) per year. It is summarized in Table 7 and Table 8 for WTP in cash and man-days, respectively.

Figure 4: Frequency curve of respondents for maximum WTP in terms of man-days



Source: Survey data, 2019

Table 7: WTP aggregation in cash from open-ended questionnaire format

Class limit (WTP in cash/month)	Class mark	Sample HH		Total HHs	
		Freq.	%	Freq.	Total WTP
0-10	5	124	45.09	27,986.6	139,932.87
11-21	16	68	24.72	15,347.5	245,559.62
22-32	27	31	11.27	6,996.64	188,909.37
33-43	38	26	9.45	5,868.15	222,989.80
44-54	49	23	8.36	5,191.05	254,361.85
55-65	60	0	0	0	0
66-76	71	0	0	0	0
77-87	82	0	0	0	0
88-98	93	0	0	0	0
99-109	104	3	1.09	677.09	70,417.83
Total		275		62,067	1,122,171.36
WTP per year					13,466,056.32

Source: Survey data, 2019

Table 8: WTP aggregation in man-days from open-ended questionnaire format

No. of man-days/month	Sample HH		Total HHs	
	Freq.	**%**	**Freq.**	**Total WTP**
0	97	35.27	21,892.72	0
1	20	7.27	4,513.96	4,513.96
2	21	7.63	4,739.66	9,479.32
4	61	22.18	13,767.58	55,070.35
5	26	9.45	5,868.15	29,340.76
6	21	0	0	0
7	14	0	0	0
8	5	0	0	0
9	5	0	0	0
10	5	1.81	1,128.49	11,284.90
Total	275		62,067	109,689.32
WTP per year				1,316,271.79

Source: Survey data, 2019

3.4. Determinants of WTP

From the binary probit model estimations, the initial bid value (BID1) and total household size (HH_SIZE) were found to have a significant influence on both the probability of households' WTP in cash and labour. However, the age of the household head (AGE) and trust in the government (TRUST) had a significant effect merely on households' WTP in cash, whereas the dependency ratio (D_RATIO), annual household income (INCOME), and households' place of residence (RESIDENCE) had a significant influence only on the probability of WTP in labour (Table 9).

The result has revealed a negative and significant effect of the initial bid value in cash and man-days at the 1% level of significance. This tells us that with an increased initial bid, households would be willing to pay less for the proposed project. This result was consistent with the economic theory of the law of demand, in which the quantity demand for a good (water hyacinth control) decreases with an increased price of that good (cash and man-days). The marginal effect has revealed that as the initial offered bid increases by one unit, the probability of the households' WTP will decline, on average, by about 2.9%, keeping the effects of other things constant. The result of this study on the initial bid was similar to the findings of (Gowing et al., 2020; Mezgebo et al., 2013;

Wheeler & Damania, 2001). Adamu et al. (2015) noted that an increase in the initial bid amount results in a decreased level of WTP for the conservation of Yankari Game Reserve in Nigeria. Belay (2018) also found a similar result in his economic valuation of soil conservation in communal lands in terms of labour contribution. Moreover, the study by Tilahun et al. (2020) reported a negative influence of the bid price in cash and in the number of working days on WTPs reliability of irrigation service.

Total household size had a negative effect on households' WTP in cash, and it was statistically significant at the 1 % probability level. It might be due to the fact that an increase in household size leads to an increase in household expenditure, which might discourage respondents' WTP for this proposed project. As the results of the marginal effect revealed, holding other factors constant, an increase of 1 member in the household will decrease the probability of WTP, on average, by 6.6%. This result is in line with the findings of Dhungana (2018) and Walle (2015). However, solid waste management studies (Dika et al., 2019; Nkansah et al., 2015b) from Ethiopia and Metropolis, respectively, showed a positive effect of household size on WTP in cash. It was due to the fact that keeping a clean environment to protect the family from a disease may increase with an increase in the number of household members. On the other hand, total household size was found to have a positive and statistically significant effect on households' WTP in man-days at the 1% probability level. It might be due to the fact that an increase in household size leads to an increase in labour supply at the household level. This might make them willing to contribute more labour for the proposed project. As the result of the marginal effect output indicated, keeping other factors constant, an increase of 1 member in the household will increase the probability of WTP, on average, by about 6.6%. The study by Gebrelibanos (2016) found a similar result.

Age of the household head was found to have significantly a positive effect on the WTP in terms of cash at 5% probability level. This positive influence could be mainly due to the fact that older people might be more aware of the importance of environmental conservation due to their life experience and have an enhanced sense of place attachment and sense of ownership due to their longer residency in the area (Cheung & Hui, 2018; Song & Soopramanien, 2019). Moreover, they might have a chance to observe the deterioration of Lake Tana due to different factors, including water hyacinth weed. The marginal effect result revealed that, keeping the other factors constant at their mean value, an increase in the age of respondents by one year will increase the probability of WTP, on average, by about 1.1 %. Similar findings were found in Harun et al. (2015), Mamat et al. (2013) and Nkansah et al. (2015a) noting that the age of the household head had a direct effect on people's WTP. But a critical review of other previous studies indicated both a negative and a positive effect of age on WTP. (Dagnew et al., 2012) in their study of WTP for improved urban waste management, for example, and (Halkos & Matsiori, 2012) in their study of WTP for coastal zone quality improvement indicated an inverse effect of age on WTP. However, Lindsay et al. (1992) found that older people were willing to pay more than younger people for coastal beach protection.

The trust of a household head toward the collector of the fund (the government) was positively related to WTP in terms of cash, and it was statistically significant at the 1% probability level. The possible explanation is that the likelihood of WTP in cash for the proposed project increases as the households trust the collector of the fund to put the contributed money in the right place. The marginal effect for this explanatory variable showed that households that responded 'yes' to the trust variable were more likely to be willing to pay than those that responded 'no', on average, by about 20.3% by keeping other variables constant. The result from this paper is in line with the study of Cvetkovich and Winter (2003), which indicated that a high level of institutional trust produces a positive influence on the acceptance of environmental policy.

At a 5% probability level, dependency ratio had a significant negative effect on the probability of WTP in man-days. The marginal effect of this variable indicated that as the dependency ratio increased by one unit, the households' probability of WTP in man-days decreased, on average, by about 7%, holding the effects of other factors constant. The possible explanation could be that households with higher numbers of dependents might find it more tiring to help their dependents rather than participate in such environmental conservation activities. Similar findings were reported by other studies (Belay, 2018; Endalew & Assefa Wondimagegnhu, 2019). Tilahun et al. (2020) also showed that a higher dependency ratio may decrease the probability of willingness to contribute to reliable irrigation service in Ethiopia.

At the 1% probability level, total annual household income was found to have a positive significant effect on the probability of households' WTP in terms of labor. The result indicated that the household with a higher income level was more likely to be willing to pay in terms of labour contribution since they could have two alternatives: participate directly as a labour force or to hire labourers on their behalf of them in harvesting the weed on the lake. This result conforms to other studies (Kanyoka et al., 2008; Lagoon et al., 2019; Moffat et al., 2011) that found a positive influence of income on people's WTP. The study by Castro et al.(2016) reported that, as the level of income increased, people would be more willing to pay for ecosystem services among stakeholder groups in a south-central U.S. watershed.

Households' location of residence was found to have a positive and statistically significant effect on the probability of WTP in man-days at the 1% probability level. This indicated that rural residents were more likely to be willing to pay in labour than urban resident households for water hyacinth control in Lake Tana. Keeping the influences of other factors constant, the result of the marginal effect of the variable showed that being a rural resident household increases the probability of WTP in labour, on average, by about 7.4% relative to urban resident households.

Table 9: Determinants of WTP

	Probit			
Variables	**Money contribution**		**Labor contribution**	
	Coef.	**Marginal effect**	**Coef.**	**Marginal effect**
BID1	-0.092***	-0.029	-0.391***	-0.029
AGE	0.035***	0.011	-0.004	0.011
SEX	-0.168	-0.052	0.369	-0.052
MARITAL	0.252	0.083	-0.223	0.083
EDUCSTATUS	0.383	0.129	-0.289	0.129
HH_SIZE	-0.207***	-0.066	0.226***	-0.066
D_RATIO	0.220	0.070	-0.354**	0.070
INCOME	0.000	-0.000	1.233***	0.000
RESIDENCE	-0.231	-0.074	0.920***	-0.074
WH_VISIT	-0.296	-0.091	0.000	-0.091
TRUST	0.653***	0.203	-0.343	0.203
Constant	1.747***		-0.391	
No. of observations	275		275	
Chi-square	97.231		160.516	
Prob > chi2	0.0000		0.0000	

***, ** and * indicates statistical significant at 1%, 5% and 10%, respectively.

4. Concluding Remarks

Lake Tana is the largest freshwater resource in Ethiopia and the third largest lake in the Nile Basin (Vijverberg et al., 2009) It is an important environmental good that has economic, social, political, religious, and ecological benefits. Even if Lake Tana has great importance to Ethiopia and the globe, currently, it is infested by water hyacinth (Eichhornia crassipes) (Firehun, 2017; Van Oijstaeijen et al., 2020). The weed is spreading over many parts of the lake since it has a fast expansion rate and invasive behaviour (Anteneh, 2014b), and it poses different problems for many human uses in freshwater bodies (Kateregga & Sterner, 2009). Once established, it is extremely difficult to eradicate (Villamagna & Murphy, 2010). Thus, individual households should commit resources in terms of money and labour so as to reduce its effect on Lake Tana. Therefore, this study was aimed at examining households' WTP for control of water hyacinth in Lake Tana at *Fogera* district. The analysis was done at the household level using cross-sectional data from 276 randomly selected households. The study elicited households' WTP through the CV methodology using the double-bounded dichotomous choice format. The study used a binary probit estimation to identify the potential determinants of WTP for the proposed project. The result revealed that, from a total of 275 willing households, about 81% of respondents were willing to pay in terms of cash, about 65% were willing to participate in terms of days of labour and about 35% of households were willing to participate in terms of awareness creation.

The mean WTP in cash for this proposed project was estimated to be ETB 26.41 per month per household, to be extended for two consecutive years. Aggregate WTP was estimated to be ETB 19,671,963 per year. The average amount of money that respondents were willing to pay in the open-ended WTP format was estimated to be ETB 19.24 per household per month. From the open-ended data format, the total perceived welfare benefit in cash for the total population of the study area was computed to be ETB 1,122,171 per month and ETB 13,466,056 per year. The binary probit model estimation indicated that the age of the household head and trust in the government were found to have a positive influence on the probability of households WTP in cash whereas the initial bid price in cash and total household size were found to have a negative effect on the probability of WTP in cash. In the labour contribution case, the estimated mean WTP in man-days for control of water hyacinth weed infestation on Lake Tana was estimated to be 3.23 man-days per month per household to be extended for two consecutive years. Aggregate WTP in labour was estimated to be 2,404,441 man-days per year, which is equivalent to ETB of 144,266,489 per year. From the open-ended format, the mean WTP in man-days was 2.89 per month per household. From the open-ended WTP survey, the aggregate WTP in man-days for the total population of the study area was computed to be 109,689 man-days (ETB 6,581,359) per month and 1,316,271 man-days (ETB 78,976,307) per year. Moreover, the estimation revealed that the initial bid value in man-days and dependency ratio had a negative effect on the probability of WTP in labour. However, total household size, total annual household income, and households' place of residence were found to have positive influences.

From the result of this study, it could be concluded that there is a high degree of household willingness to participate in the proposed project in terms of cash and labour contributions. The estimated total WTP from this study can be considered the societal benefits of controlling this invasive weed on the lake and can be used in future cost-benefit analyses for policy formulation. However, the estimated mean WTP from the open-ended format was smaller than the close-ended format, which might be due to the human being's free-riding behaviour from the benefit of controlling water hyacinth at the expense of others. As the result of the econometric analysis indicated, households' WTP was negatively responded to with an increase in initial bid prices in terms of both cash and labour contribution, which is consistent with the economic theory of the law of demand. In addition to that, the income level of the households was positively related to the WTP in labour indicating that environmental good is a normal good for which demand increases with an increase in income level. Moreover, the place of residence makes a difference in choosing between money payment and labour contribution. The result indicated that rural households were more interested in labour contributions than in cash payments for water hyacinth infestation control in Lake Tana.

Following the findings obtained from this study, the following issues are forwarded as a recommendation.

1) The government should consider and design strategies to diversify households' income since it was positively related to WTP for the proposed project.
2) In valuing the conservation demand of Lake Tana from water hyacinth infestation, the policymakers should consider the modes of payments (cash and labour) in rural and urban areas, and elicitation formats of WTP.
3) The government also should consider its accountability and transparency in resource utilization for this proposed project since trust of households on the government was the most significant variable among the determinants of WTP in cash.
4) To suggest for future works, since this study was limited to the control of water hyacinth infestation in Lake Tana, it might be interesting to value on

the whole ecosystem of Lake Tana for its sustainable use. As this study indicated, there is a possibility of measuring households WTP in terms of awareness creation besides money payment and labour contribution. Thus, one can possibly use this methodology to measure WTP in terms of teaching per day. Moreover, since Lake Tana has a recognized national and international significance, one can measure the WTP of the people for the conservation of the lake beyond the near districts and towns as well as possibly outside Ethiopia. It is also interesting to study the impact of water hyacinth specifically on fishing, crop production, biodiversity, water transport and other benefits of Lake Tana or on the whole lake ecosystem in general.

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