Farmers' preferences towards water hyacinth control in Lake Tana: a contingent valuation study

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ABSTRACT

Lake Tana is the most important fresh water lake in Ethiopia and by extension the Horn of Africa. Besides pressures on water quality resulting from urbanization and deforestation, the invasion of the exotic water hyacinth poses new threats to the ecosystem. Water hyacinth or *Eichhornia crassipes* – endemic to South America – is widely considered as the world's worst aquatic invasive weed. In 2011, the weed appeared on the northern shores of Lake Tana. It rapidly expanded in south-eastern direction. The lake area affected by water hyacinths was last estimated in 2015 at 34,500 ha, which equals 16% of the total lake surface. In this research, the perceived benefits of water hyacinth control and eradication for the rural population inhabiting the northern and north-eastern villages bordering Lake Tana, is investigated. In the areas studied, the population largely depends on farming and (less importantly) on fishing. An assessment of the total economic value to inhabitants of the infested shores of Lake Tana was conducted through a contingent valuation survey. Willingness to pay was measured in labor and cash money. A total of 240 households were interviewed in order to assess the value of water hyacinth control to the ecosystem services provided by Lake Tana. The willingness to contribute to the hypothetical Lake Tana Protection Program was questioned for two scenarios: *status quo* (current situation) and *improvement* (complete removal of infestation). Nearly all respondents were willing to contribute labor or cash in order to control and improve the current situation. The mean willingness to pay was estimated at 440.9 ETB yearly (≈ €13.5) for the status quo scenario and 764.4 ETB yearly (≈ €23.4) for the improvement scenario. The mean willingness to contribute labor was estimated at 32.6 man-days yearly for the status quo scenario and 51.2 man-days yearly for the improvement scenario. The benefits of control obtained by the study can be compared with costs of control or cost of investing in alternative destinations for harvested water hyacinths to provide potential justification for decision making: control/eradication expenditures vs. infrastructure investments for water hyacinth utilization.

Highlights

- A contingent valuation to estimate the impact of water hyacinth infestation in Lake Tana
- Conservative extrapolations indicate an impact of over half a million euros a year on local smallholders
- Assumption of cash constraint in developing countries might not be valid when livelihood deeply affected

- Urge for *adaptation* to the newly defined ecosystem and turn ecosystem disservice into ecosystem service

1. Introduction

Lakes and wetlands offer environmental, ecological, socio-economic, cultural and other benefits. These benefits are characterized as ecosystem services, since it is how ecosystems contribute to human wellbeing (Costanza et al., 1997). Similarly to dryland ecosystems, lake-wetlands increasingly face the threat of degradation, often a result of urbanization, overexploitation, poor water-waste management and unsustainable farming and fishing, which stems from an insufficient understanding and acknowledgement of the values and functions (Schuyt, 2005). However, in contrast to drylands, implications of degradation on the stakeholders are less intensively studied, leading to scant data issues (Xu et al., 2018) and often unsustainable management. With regard to sustainable development, research on these ecosystem services gains momentum (McDonough et al., 2017). In this context, socioeconomic impact assessments are increasingly relevant with regard to water management and control. The values that an ecosystem provides as well as the benefits obtained from its ecosystem services determine the willingness to protect and restore ecosystems (Mueller et al., 2016). Given the non-replaceable nature of many ecosystem services, valuation exercises stipulate the importance of healthy, well-managed natural environments (Mueller et al., 2016).

A perspective often neglected in traditional conservation policies, is that of ecosystem disservices (EDS) (Campagne et al., 2018; Vaz et al., 2017). The perspective of ecosystem disservices originates from criticism on the original ecosystem services (ES) concept, which considers merely beneficial influences of ecosystems. Complementary to ES, EDS take account of the undesirable and (economically) harmful effects of ecosystems (Vaz et al., 2017), or as stated by Shackleton et al. (2016): '*Ecosystem disservices are the ecosystem generated functions, processes and attributes that result in perceived or actual negative impacts on human wellbeing.'* Alien invasive species (AIS) are defined as those non-native species threatening native ecosystems, habitats or species (Pejchar & Mooney, 2009). This does not imply that alien species are necessarily negative, but the existence of AIS could lead to the generation of EDS. Yet, EDS have been sporadically considered in socio-ecological challenges, like AIS (Vaz et al., 2017). In the context of lakes and wetlands the evaluation of ecosystem services has

progressed significantly and the threat of AIS in particular, the perspective of potential socioeconomic implications of ecosystem disservices is less documented.

The potential downgrading implications of AIS have been recognized and led to the adoption of target 9 in the Aichi targets (2011-2020) set by the Convention of Biological Diversity (CBD), agreed at the Nagoya conference by 196 nations. This target 9 prioritizes the identification of invasive alien species and pathways, as well as priority species to be controlled or eradicated by 2020. Regarding this, the National Targets to the Aichi Biodiversity Targets by Ethiopia objectify the following: "By 2020, the area invaded by invasive species is reduced by 75% and measures are in place to regulate and monitor invasive species, including newly emerging ones" (Convention on Biological Diversity, 2019). In the light of such objectives, assessing the incurred damage by invasive species is a fundamental aspect. In this research, a valuation of the ecosystem disservice of water hyacinth on local smallholder farming communities around Lake Tana, Ethiopia was conducted.

The Lake Tana Biosphere reserve offers a wide array of ecosystem services. Being the source of the Blue Nile river (Anteneh et al., 2015), the quality and supply of water of Lake Tana influences all downstream areas, contributing to the ecosystem services provided there as well. The influence of the ecosystem services considered will be limited to the Lake Tana catchment area. First of all, Lake Tana and its fertile wetlands provide important agricultural value not only to people inhabiting the shores, more remote areas also depend on the irrigation services of the lake (Worku, 2017). Crop production and communal grazing lands are the dominant agricultural activities, (Wondie, 2018). Secondly, many kebeles (i.e. the smallest administrative unit in Ethiopia) are only accessible by boat (Anteneh et al., 2015). The islands on Lake Tana have significant spiritual value with their Christian Orthodox monasteries and churches. These commercial and cultural values contribute to the relevance of transportation services provided by Lake Tana. Thirdly, there are approximately 5000 fisherfolk around Lake Tana, directly contributing to the livelihood of many (Amare et al., 2018). Fourthly, the water from Lake Tana forms an inlet for several hydroelectric power plants (Tesfaye et al., 2016). Finally, the importance of tourism to the region is increasing, with Lake Tana as one of the main attractions (Anteneh et al., 2015). Apart from the ecological value of the Lake Tana Biosphere Reserve, the abovementioned ecosystem services contribute to the significant economic, social and cultural added value of Lake Tana.

According to Anteneh et al. (2014), Lake Tana was formally recognized to be infested with water hyacinths as from 2011. Water hyacinth or *Eicchornia Crassipes* is an aquatic AIS, possibly originating from Brazil from where it spread to nearly all of the Southern and Central

American countries. Almost all countries between 40°N and 40°S face (the threat of) infestations on lakes, slowly moving rivers or swamps (Malik, 2007). Water hyacinth is a free-floating plant, known for its rapid reproduction and its tendency for mat-forming. Infestations with water hyacinth are considered to lead to unfavorable ecological and socio-economic changes. Penfound Wm and Earle (1948) already mention of how water hyacinth infestations induce damage: (1) obstructing navigation, (2) impeding drainage, (3) destroying wildlife resources, (4) reducing out-of-doors recreation, and (5) constituting a hazard to life. Classified as one of the world's most productive plants and worst aquatic weeds (Lowe et al., 2000), eradicating an infestation is extremely challenging. In 2017 and 2018, local awareness of the problem increased drastically through media coverage aimed at informing the public (e.g. BBC News (2018)). Moreover, Anteneh et al. (2015) concluded that regardless of the communal efforts of physically removing water hyacinth, the weed remains difficult to control. Due to the pervasive nature of the water hyacinth, management actions focus on minimizing the socio-economic and ecological impact (Malik, 2007; Villamagna A & Murphy B, 2010).

In order for the ecosystem to be managed sustainably, information is needed. However, with water hyacinth only recently invading Lake Tana, research on the issue is thus far limited. Research on water hyacinth in Lake Tana has been focused on mapping the coverage and on qualitative data collection (Anteneh et al., 2014; Anteneh et al., 2015; Asmare, 2017; Sewnet & Kameswara, 2011). Previous studies on water hyacinth in the area identified the drivers for (potential) economic damage:

- Gezie et al. (2018) argued that the infestation has a significantly negative impact on the water quality and biotic communities and serves as a breeding ground for mosquitos and other vectors.
- In (Dejen et al., 2017) it is mentioned that water hyacinth reduces fish catches and decreases available landing sites.
- Anteneh et al. (2015) describes clogging of waterways, irrigation channels and invasion of communal grazing lands.

Although these elements have been identified, the extent of the socio-economic implications has not been investigated with direct stakeholders at the site. According to Schuyt (2005), a major cause for the failure of wetland management in African countries is the lack of understanding of the economic value of these wetlands.

The aim of this research is to report and explain the economic consequences to local smallholders by the recent water hyacinth infestation, thus the monetary extent of the EDS. There is a need to uncover the perceived damage to local farmholders caused by water hyacinth,

to allow environmental economists to use reliable inputs for future decision-making and ecosystem management. Results of this research are expected to provide an input for cost-benefit analyses, potentially justifying the cost of control/eradication measures. After all, the Millennium Assessment states that decisions influencing wetlands require full information on benefits and values of the ecosystem (Millennium Ecosystem Assessment, 2005). Currently, there is no national wetland policy in Ethiopia (Wondie, 2018), emphasizing the importance of scientific proof on the E(D)S. All this underlines the relevance of a valuation exercise on the water hyacinth issue in Lake Tana, Ethiopia. A similar study was conducted in the city of Bahir Dar with urban dwellers (Tesfa, 2019). However, local people's perception is rarely considered (Xu et al., 2018), hence this participatory study with direct stakeholders – and currently the first victims - in the water hyacinth dispute: local smallholders on the infested parts of the Lake Tana shores.

Concretely, the following objectives are defined: (1) estimate the impact of the water hyacinth infestation on Lake Tana on local smallholders (in terms of money and in terms of labor contributed) ie. to evaluate the breadth of support for interventions to control water hyacinth infestation; (2) examine how demographic characteristics influence the willingness to contribute; (3) compare and interpret the findings with similar other water hyacinth valuations; (4) evaluate the influence of the payment vehicle on the willingness to contribute and the assumption of a cash constraint.

2. Methods and materials

2.1 Study area

Lake Tana is located in the Amhara National Regional State, in the north-western part of Ethiopia. The lake surface covers between 3000-3600 km^2, whereas total lake catchment includes 15,096 km^2 (Setegn et al., 2008). Lake Tana is shallow with a mean depth of 8 meters and ranging up to a maximum depth of 14 meters (Anteneh et al., 2015). It lies at an elevation of 1800 meters above sea level. Formed circa 5 million years ago by volcanic activity, Lake Tana is the largest freshwater body in Ethiopia and accounts for approximately 50% of Ethiopia's surface freshwater reserves. It is the source for the Abay river (Blue Nile) which makes up 85% of the total Nile River discharge (Sewnet & Kameswara, 2011). The Lake Tana ecosystem was designated as a 'Biosphere Reserve' by UNESCO in 2015. This Man and Biosphere Reserve program aims at "*improving the overall relationship between people and*

their environment" (UNESCO, 2017). Lake Tana is of significant ecological and socio-economic importance (Anteneh et al., 2015).

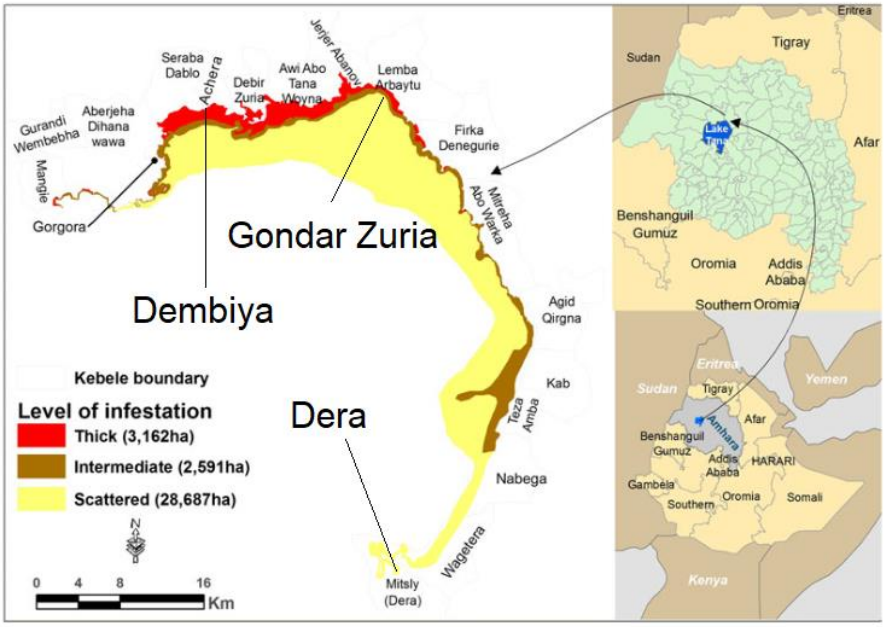

Fig. 1: map of the Lake Tana water hyacinth infestation, adaptation on Dejen et al. (2017)

According to figures of the Ethiopian government, 85% of people in the Amhara Regional State depend on agriculture as the main source of income. Other main sources of income in the region are trade, fishing, tourism and sand mining (Ethiopian Government Portal, 2018). Poverty and illiteracy levels are high in the rural landscape of the study area. High population growth rates and migration have contributed to the extensive urbanization and augmented direct dependence on the ecosystem services provided by the Biosphere Reserve. Increased land degradation through overexploitation of the wetland resources and poor waste management have increased the nutrient levels and led to eutrophication of the Lake Tana Basin (Wondie, 2010). These circumstances benefitted the actual outbreak of water hyacinth on the northern shores of Lake Tana. This outbreak was officially recognized in 2011, when a coverage of 4,000 ha was reported. The most recent coverage survey by Anteneh et al. (2015) estimates 34,500 ha of the Lake is affected by water hyacinth. Wondie (2018) identified water hyacinth now as the main threat for wetlands in the north of Lake Tana. In what follows, this level of infestation is defined as the *status quo scenario*. Currently, households in the area are expected to participate in regular physical removal campaigns. Water hyacinth infestations follow a cyclical pattern (Ongore et al., 2018) and these campaigns are organized by the local authorities in every district during the period of expansion at the end of the rainy season (September-January). Concretely, the regular campaigns are organized once or twice a week. As a household of the issuing kebele,

at least one household member is obliged to contribute. On top of this, larger events are organized where people from the wider areas are mobilized.

The study area for this research was selected from the "Water hyacinth coverage survey" conducted by Anteneh in 2014 and 2015. Out of five infested districts or woredas, three were chosen based on severity of infestation, accessibility and recent developments in water hyacinth coverage. In correspondence with local experts, the kebeles suitable for the study were assigned. More precisely, the choice of kebele depended on the expertise and familiarity of development agents, in order to facilitate the process. In each of the three chosen woredas, one kebele was surveyed: Achera Mariam in Dembiya, Lemba Arbayitu in Gondar Zuria and Tana Mitsili in Dera (indicated on fig. 1). According to Anteneh (2015), the infestation in Tana Mitsili is the most recent and consequently the least severe. On the contrary, Achera Mariam on the northern shore is close to the Megech river mouth, where water hyacinth infestation started in 2011. Lemba Arbayitu was also infested early, the water hyacinth coverage in Lemba Arbayitu is considered the most severe. A sample of households proportional to the population in every village was targeted. After revision, 240 out of 300 distributed questionnaires were filled out correctly.

2.2 Valuation method

The ecosystem services that are provided by Lake Tana can be described as 'public goods'. The use of these services is characterized by non-rivalry and non-excludability (Richard T Carson & Mitchell, 1989). As a result of the water hyacinth infestation (i.e. ecosystem disservice), these 'public goods' cannot be enjoyed to the maximum. To estimate the cost of the disservice that is generated by the alien invasive species, the contingent valuation method (CVM) was applied (Loomis et al., 2000). The CVM is a stated-preference method for economic valuation: surveys are carried out to elicit respondents' willingness to pay and/or willingness to contribute labor (Richard T Carson & Mitchell, 1989; Cawley, 2008).

A contingent valuation (CV) survey was carried out to derive the willingness to contribute under the scenario of water hyacinth control and complete removal. Different scenarios to the hypothetical market can provide additional insight in the utility derived from the ecosystem as well as the severity of the problem statement. Contingent valuation rests on the assumption that the economic measure of benefit is the utility stakeholders derive or in this case, the disutility resulting from EDS. Considering the nature and location of the study, CV was deemed most suitable. First of all, water hyacinth currently is not exchanged in regular markets, nor is any eradication effort (e. g. NGO), making revealed preference methods challenging. Additionally,

all local households are familiar with the existence and hindrance of water hyacinth and benefit from removal initiatives, which can be defined as a public good. Another commonly used stated preference method is a choice experiment. However, choice experiments are suited to assess economic value of certain attributes of an environmental good (Holmes et al., 2017), which is not the objective with this study. Lastly, the ability of CV to measure both use and non-use values makes it qualified to perform the analysis.

2.3 Data collection

A formal structured survey was conducted in November 2017. This period coincides with the harvesting season for water hyacinth. From September/October to January – at the end of the rainy season - the weed expands most rapidly. During this period local communities organize campaigns to manually remove the water hyacinths. These manual removal campaigns usually consist of harvesting the water hyacinth plants and piling them up on the shores (picture in Appendix C).

The questionnaires were prepared in English and pretested with Amharic translators. Pre-testing took place at a farming conference in Dera woreda. These pre-tests were organized to test the survey design, as well as people's understanding of the hypothetical market that was created and their relatedness to the topic of water hyacinth. A total of 15 farmers of a village similar to those of the study area (i.e. same woreda and water hyacinth infested shoreline) were surveyed in the presence of Bahir Dar University (BDU) personnel, afterwards the survey was revised. Revisions mainly involved adjustments to the ranges of contributions. The revised survey was translated to Amharic. The surveys were all carried out by trained development agents, in the company of local experts and the first author (Van Oijstaeijen, W.). The units of analysis in this study are households living in the kebeles mentioned in 2.1. Households were chosen because contributions to public goods are assumed to be made as a household (e.g. current land tax). In the Lake Tana area, the census in 2007 reported that households comprise 5.0 members on average (Stave et al., 2017). Respondents were chosen using clustered random sampling. Public gatherings such as church days and public holiday gatherings in local communities were seized to approach as many respondents as possible for face-to-face interviews. The selected kebeles are all situated on the shores of the lake. Inhabitants in these kebeles live from crop production and livestock production.

One of the conditions for credible CVM outcomes is familiarity of the respondents with the proposed product (Richard T. Carson et al., 2001), hence why local communities on infested

shores were targeted. In the region, 80% of the household heads are men and even when the man is no household head (HH), he is still primarily responsible for economic decisions within the household. In consequence of the above reasons, only men were interviewed for the CVM. Furthermore, women and children were interviewed to provide additional contextual information on the water hyacinth outbreak, seasonal influences and the impacts of water hyacinth on their daily lives.

2.4 Questionnaire design

Respondents were first asked some general, introductory questions about their use and appreciation of Lake Tana. Here, respondents have the opportunity to value (1-5 scale) the importance of Lake Tana for different activities, for example: farming, fishing, sand mining, religious purposes, etc. The main purpose of these questions is to comfort respondents. Subsequently, enumerators provided the respondent with an information card (see Appendix B). This information card states the current water hyacinth problem and the threats posed by the issue to the ecosystem (Bräuer, 2003). The information card was read by the enumerator in case of illiteracy. Following the problem statement, the hypothetical market called "The Lake Tana Protection Program" was explained. The Lake Tana Protection Program was defined as an hypothetical removal campaign irrespective of any eradication method (biological/physical/chemical). The objective of the study is to obtain the aggregated benefits of water hyacinth control/eradication. Since eradication of water hyacinth has been attempted repeatedly, it is assumed that potential distrust towards certain eradication methods could influence the willingness to contribute statement and rather reflect willingness to contribute for the method than for the eradication itself. After this, the willingness to contribute labor (WTCL) or willingness to pay (WTP) elicitation questions were posed. The end of the survey consists of socio-demographic information questions (age, farming experience, income, etc.). In drafting the survey and processing the results, guidelines for value elicitation surveys as formulated by the NOAA panel were taken into account (Arrow et al., 1993).

Three different formats of the survey were designed, dependent of the mean of contributing to "the Lake Tana Protection Program". Every respondent got assigned one survey format out of these three randomly: cash format, labour format or mixed format. In the 'cash money' format, respondents' willingness to pay in terms of a yearly amount of money in Ethiopian Birr (ETB) was asked. In the 'labor' format, respondents expressed their willingness

to contribute labor to The Program in man-days[1] yearly. In the 'mixed' format, respondents were given the possibility to contribute in cash, in labor, in a mix of both or to not contribute at all. Dependent on the answer respondents in the mixed survey provided to this contribution question, a set of contingent valuation questions were asked. Respondents were assigned one of the above three (cash, labor or mixed) formats randomly. The addition of contribution in terms of labor, contrary to standard contingent valuation studies has several reasons. First, it was hypothesized that households are not indifferent to contributing in money and labor. Previous studies introducing both cash and labor contributions in developing countries, found the cash constraint and low valuation of time as main drivers (Kamuanga et al., 2001; Swallow & Woudyalew, 1994; Tilahun et al., 2015). Moreover, in rural Ethiopia, labor markets are very restricted, implying the limited ability of job mobility (Swallow & Woudyalew, 1994; Tilahun et al., 2015). A low willingness to pay does not necessarily imply reluctance towards the Program. Household incomes are often inadequate to meet basic needs, a sole willingness to pay question may not fully reflect the value of the Lake Tana Protection Program. Secondly, by offering the option, the strength of this assumed preference towards labor contribution can be measured. Other studies have opted for WTCL, without surveying the WTP. Often, these studies use the wage rate of time to convert these values into monetary outcomes. The authors believe that – given the low valuation of time and labor market restrictions – such conversions may add bias.

Two scenarios for the hypothetical market were developed: a status quo scenario and an improvement scenario. In the status quo scenario, the Lake Tana Protection Program would keep the level of water hyacinth infestation constant at the current level. In the improvement scenario, the Lake Tana Protection Program is presented to entail the complete removal of all water hyacinth. The latest scenario is merely hypothetical since the complete removal of an infestation is often extremely challenging. Respondents were clearly informed about the form and frequency of the contribution (Richard T Carson & Mitchell, 1989).

Polychotomous questions allow the interviewee to receive additional information, while not deviate from the Referendum Format preferred by the NOAA. The fact that it is superfluous to ask prompting questions, saves the enumerator effort and consequently time (Cameron & Huppert, 1989). In addition, respondents may be uncertain to explicit a single point of personal value, but rather have ranges in mind (Cameron & Quiggin, 1994), using intervals can account for this issue. However, the formulation of predefined (as a product of the pilot surveys)

[1] Man-days are defined as 8 hours of work by an adult man.

intervals may cause anchoring bias. The size and values of the intervals formulated in the actual survey were the result of the pretests. The result of offering ranges to choose from is similar to a payment card approach and its processing (Welsh & Poe, 1998).

If a respondent of the mixed survey stated to be willing to contribute a combination of cash and labor, an open-ended question was asked to express their maximum combination of cash and labor. Open-ended questions are often less favored due to the possible occurrence of non-responses and protest zeros (Richard T Carson & Mitchell, 1989). Hence why enumerators were informed to clearly explain the purpose and in case of zero vote ask for the underlying reason. After the elicitation of WTP/WTCL in the status quo scenario, respondents proceeded to an identical question on the WTP/WTCL in the improvement scenario. The full survey can be found in Appendix A.

2.5 Econometric specification

The data obtained by the polychotomous question are interval censored. The objective is to formulate a mean WTP/WTCL with confidence intervals. According to Cameron and Huppert (1989), regression models with an interval-censored dependent variable are preferably estimated with an efficient maximum likelihood (ML) function, called 'interval regression'. This is especially relevant when intervals are coarse, which is the case for this study. Another attribute determining the choice of the estimation technique is the amount of zero responses. A tobit regression is preferred when the WTP data contain a high amount of zero bids (O'Garra & Mourato, 2007) and with open-ended data. This was not the case in this study which had only 3,5% zero bids. The interval regression for interval and right/left-censored data was utilized in a previous study by Cawley (2008), using the intreg command in STATA 10. For this study, a more recent version of STATA (15) was used.

Table 1
Definition of regressors utilized in interval regression

Variables		Description	Mean (SD)
Age	Discrete	Continuous variable in years	41.6 (13.4)
Location	Categorical	1 if respondent lives in Achera Mariam, 2 if respondent lives in Lemba Arbayitu and 3 if respondent lives in Tana Mitsili	
Farming experience	Ordinal	1 if respondent has 0-5 years of farming experience, 2 if respondent has 6-10 years of farming experience, 3 if respondent has 11-20 years of farming experience and 4 if respondent has more than 20 years of farming experience	3.0 (1.0)

Education	Ordinal	1 if respondent can't read or write, 2 if respondent has no formal education, 3 if respondent has attended formal education	1.6 (0.7)
Local conference attendance	Binary	1 if respondent attended a water hyacinth conference, 0 if not	0.7 (0.4)
(Farming) Income	Ordinal	1 if income is smaller than 10,000 ETB yearly, 2 if income is between 10,000-25,000 ETB yearly, 3 if income is between 25,001-50,000 yearly and 4 if income is over 50,000 ETB yearly	2.5 (0.8)

For all respondents, a water hyacinth infested Lake Tana yields some utility given by $U(WH_1, S, I, \varepsilon_1)$. With WH a vector for the evolution of infestation (WH_0 equals no infestation, WH_1 is the current state, WH_2 would imply that the lake surface is completely covered), S is the vector of socio-economic characteristics, I represents income and ε denotes randomness in the data. Their utility of a non-infested Lake Tana is given by $U(WH_0, S, I, \varepsilon_0)$. The level of infestation reduces from WH_1 to WH_0. An individual has a willingness to pay Y* for this environmental improvement such that (Ian J Bateman & Willis, 2001):

$$U(WH_1, S, I, \varepsilon_1) = U(WH_0, S, [I\text{-}Y^*], \varepsilon_0)$$

This expression is similar for WTCL if the amount of leisure would be included. L denotes total leisure, Y* now denotes a bid in labor terms:

$$U(WH_1, P, X, L, \varepsilon_1) = U(WH_0, P, X, [L\text{-}Y^*], \varepsilon_0).$$

Let x_i be the vector that includes the income/leisure stack and the socio-economic characteristics. ε_i is the random term of the individuals' WTP/WTCL, which is assumed to be normally distributed with zero mean and constant error. β is the vector of interval regression coefficients, with $i = 1,\ldots,n$ individuals in the questionnaire sample. Cameron and Huppert (1989) have defined a maximum-likelihood *interval regression*. Such that:

$$Y^* = x_i\beta + \varepsilon_i$$

In the interval-censored data, the true WTP/WTCL Y* of a respondent is not expressed as a point value, but lies between an upper threshold (t_k) and lower threshold (t_{k-l}) in each interval. Expressed as follows by Whitehead et al. (1995):

$$\Pr[Y_i^* \subseteq (t_k, t_{k-l})] = \Pr\left[\frac{(t_k - x_i\beta)}{\sigma} < z_i < \frac{(t_{k-l} - x_i\beta)}{\sigma}\right]$$

$$\text{With } z_i = \frac{x_i\beta}{\sigma}.$$

Similarly, Cawley (2008) describes the single likelihood contribution of an individual i with willingness to contribute in the interval [Y_{i1}, Y_{i2}] as:

$$\Pr\left(Y_{i1} < x_i\beta + \varepsilon_i < Y_{i2}\right)$$

In the survey, people indicating to be willing to pay more /contribute more labor than the maximum-stated amount are asked an open-ended follow-up question to reveal the maximum willingness. In the interval regression, these answers are treated as right-censored in the absence of an upper bound. This likelihood contribution is described as $\Pr\left(Y_{i1} < x_i\beta + \varepsilon_i\right)$. In the past, the maximum likelihood functions that were used are all estimated with the *intreg* commando in STATA 15. The individual mean WTP/WTCL is estimated using the regression's results. Robust standard errors were used to calculate the 95% CI on the mean WTP/WTCL. The baseline model includes all variables examined in the questionnaire. As a mean of control, ordered logistic regressions were run for every model to verify the interval regression's conclusions. For the mixed survey regional differences in responses on the contribution question were examined through a Fisher's Exact test. This is commonly used to examine the relation between two categorical variables when one or more cells have an expected values ≤ 5 or for small sample sizes in general (McDonald, 2009).

3. Results

3.1 Descriptive analysis

A total of 240 households correctly completed the contingent valuation questionnaire, of which 3.75% stated zero WTP/WTCL. Table 1 provides an overview of the participants' demographics. The exploratory questions in the beginning of the survey revealed that respondents value Lake Tana most importantly for the services it provides supporting crop production (90%) and livestock farming (71%). Other services stated as important are recreational (47%), religion (32%) and fishing (30%). In additional qualitative interviews, respondents emphasized the burden that water hyacinth is in the daily life. Especially in Lemba Arbayitu, Gondar Zuria people expressed feelings of hopelessness towards the water hyacinth outbreak and possible eradication of water hyacinth.

Table 2
Descriptive statistics of survey respondents

Variable	n	%	Variable	n	%
Location			**Main type of agricultural activity**		
Dembiya	58	24	Crop production	22	9
Gondar Zuria	123	51	Livestock	3	1
Dera	59	25	Mixed	215	90
Age group			**Estimated annual farm income**		
18-24	10	4	< 10,000 ETB	36	15
25-34	69	29	10,000-25,000 ETB	89	37
35-44	73	30	25,001-50,000 ETB	79	33
45-54	40	17	> 50,000 ETB	36	15
55-64	27	11	**Estimated annual off-farm income**		
65+	21	9	< 5,000 ETB	227	95
Household head is owner of plot(s)	232	97	5,000-10,000 ETB	10	4
Farming Experience of household head			10,001-20,000 ETB	3	1
0-5 years	20	8	> 20,000 ETB	0	0
6-10 years	55	23	**Highest education of household head**		
11-20 years	59	25	Can't read and write	138	58
> 20 years	106	44	No formal education	58	24
			Grades attended	44	18
Has participated in local conferences about water hyacinth	165	69			

The regressors utilized for the interval regression are outlined in table 2. Since the 'HH is owner of the plot(s)' and 'Main type of agricultural activity' questions both had one very dominant answer, the additional information to the model is dismissible. In the 'Estimated annual off-farm income' the dominance of the first category is due to the high percentage (95%) of zero responses. In the study-area there is little alternative for income but farming, for the modelling only the farm income is counted. The independent demographic variables included in the model are respondents' age, location, farming experience, education, water hyacinth conference attendance and (farming) income. Age and income were treated continuously, where all other predictors were included as factor variables.

The baseline model was defined as the full model including all regressors. Subsequently, the regressions were ran without the indicator 'Education', described by the transformation from model output (1) to model output (2). Careful analysis of the regressors revealed pairwise correlation between 'Education' and other predictors. If any further reduction improved the log

likelihood, a further simplification was accepted, depicted by (2) to (3). The coefficient estimates are listed, with robust standard errors in parentheses and statistical significance is illustrated with asterisks.

3.2 Willingness to pay

In the status quo scenario respondents expressed their WTP for the water hyacinth infestation remaining at the same level as it is today.

Table 1
WTP interval regression results for the status quo scenario

Variable	(1)	(2)	(3)
Age	-9.5 (5.1)*	-10.2 (4.7)**	-10.3 (4.8)**
Gondar Zuria	-133.1 (88.0)	-122.1 (83.1)	-124.2 (57.2)**
Dera	-5.1 (92.2)	3.1 (89.8)	
Farming Experience 6-10 years	26.1 (117.4)	24.5 (122.1)	24.08 (121.8)
Farming Experience 11-20 years	161.8 (128.1)	168.7 (128.8)	168.6(129.1)
Farming Experience > 20 years	174.5 (129.6)	176.6 (130.1)	176.6 (130.0)
No formal education	-35.3 (79.5)		
Grades attended	22.5 (82.4)		
Local conference	89.9 (69.0)	97.6 (65.9)	98.0 (65.0)
Income	84.9 (36.2)**	79.2 (34.2)**	79.4 (34.6)**
Constant	247.4 (136.7)*	251.0 (140.3)*	252.5 (133.4)**

*Note: * p < 0.10, ** p < 0.05, *** p < 0.01*

Willingness to pay for the program appears to be positively influenced by the household's income. For the baseline model, a household stating to be in a higher income category is estimated to be willing to pay 84.9 ETB more than a household in the lower income category. The sample has an interval regression estimated mean willingness to pay of 440.9 ETB yearly (≈ €13.5) for the status quo scenario, with 95% CI [376.8; 505.0] and robust standard error of 32.7. In regression model (2), the location predictors imply an effect relative to the base (Dembiya). In order to observe the absolute effect of Gondar Zuria, the predictor 'Dera' was left out in advancing to regression model (3).

For the improvement scenario, implying water hyacinth eradication, interval regression coefficient estimates are shown in table 4. The Lake Tana Protection Program has a mean WTP value of 764.4 ETB yearly (≈ €23.4), with 95% CI [647.2;881.6] and robust standard error of 59.8.

Table 2
WTP interval regression results for the improvement scenario

Variable	(1)	(2)	(3)
Age	-5.0 (10.3)	-4.6 (9.9)	-4.6 (9.9)
Gondar Zuria	-283.3 (157.6)*	-290.4 (144.1)**	-300.1 (106.9)***
Dera	19.4 (163.0)	13.8 (152.0)	
Farming Experience 6-10 years	-144.7 (162.5)	-147.8 (159.0)	-149.7 (156.2)
Farming Experience 11-20 years	105.8 (203.0)	98.9 (190.7)	98.3 (190.3)
Farming Experience > 20 years	63.9 (213.8)	60.6 (208.2)	60.4 (207.5)
No formal education	21.5 (146.1)		
Grades attended	-1.1 (160.9)		
Local conference	166.5 (129.9)	164.6 (122.5)	166.2 (120.5)
Income	182.5 (75.6)**	185.3 (70.6)***	186.3(71.1)***
Constant	388.4 (205.4)*	391.8 (193.0)**	398.6 (178.0)**

*Note: * p < 0.10, ** p < 0.05, *** p < 0.01*

Recurrently, the statistical significance is most prominent for the variables 'Income' and 'Gondar Zuria' (Lemba Arbayitu, Gondar Zuria). For the household's income, the relation to willingness to pay is intuitive and the consistent direction of the estimating coefficients confirms the intuition. For the location Lemba Arbayitu, underlying factors could explain their reduced WTP relative to the other kebeles in the study-area. Expectedly local households are willing to pay significantly more for the improvement scenario compared to the status quo scenario.

3.3 Willingness to contribute labor

Respondents who were interviewed through the WTCL survey stated their willingness to contribute labor in terms of personal man-day labor contribution.

Table 3
WTCL interval regression results for status quo scenario

Variable	(1)	(2)	(3)
Age	-0.3 (0.3)	-0.4 (0.3)	-0.4 (0.3)
Gondar Zuria	2.6 (4.0)	3.3 (3.6)	
Dera	8.6 (3.4)***	8.9 (3.4)***	6.8 (3.0)**
Farming Experience 6-10 years	6.4 (6.7)	6.0 (6.6)	5.4 (6.3)
Farming Experience 11-20 years	12.4 (6.9)*	12.3 (7.0)*	11.7 (6.7)**
Farming Experience > 20 years	16.1 (6.7)**	16.6 (6.8)**	16.7 (6.8)***
No formal education	-0.8 (4.1)		
Grades attended	3.6 (6.9)		
Local conference	8.1 (3.3)**	8.0 (3.3)**	7.8 (3.3)***
Income	-2.5 (1.9)	-2.2 (1.8)	-1.8 (2.0)
Constant	23.2 (10.2)**	22.9 (10.2)**	27.5 (6.8)***

*Note: * p < 0.10, ** p < 0.05, *** p < 0.01*

The estimations of the interval regression based on the status quo scenario data can be found in table 5. Respondents living in Tana Mitsili, Dera were willing to contribute significantly more man-days of labor compared to the other kebeles. Moreover, the attendance of water hyacinth local conferences (positively) influences the WTCL significantly. Model reduction from (1) to (2) entails the removal of the variables Education due to high correlation with other regressors.

The mean WTCL of the sample is 32.6 man-days yearly with 95% CI [29.1; 36.1] and robust standard deviation equal to 1.8. The positive relation between the Farming Experience and the eventual WTCL is logical: respondents with more farming experience are better aware of the influence on the farming activity due to water hyacinths.

Table 4
WTCL interval regression results for improvement scenario

Variable	(1)	(2)	(3)
Age	-0.2 (0.5)	-0.3 (0.4)	-0.3 (0.4)
Gondar Zuria	-3.5 (6.4)		
Dera	7.1 (6.6)	7.7 (6.8)	9.2 (5.7)*
Farming Experience 6-10 years	-0.4 (10.5)	-1.1 (10.6)	-0.7 (10.3)
Farming Experience 11-20 years	11.8 (10.8)	11.6 (11.0)	12.3 (7.2)
Farming Experience > 20 years	12.4 (10.6)	13.3 (10.7)	14.1 (9.0)
No formal education	-1.9 (6.9)		
Grades attended	6.0 (10.1)		
Local conference	14.2 (5.1)***	14.1 (5.3)***	14.2 (5.4)***
Income	0.7 (2.9)	1.3 (2.7)	1.1 (2.8)
Constant	33.0 (14.9)**	31.2 (13.7)**	33.1 (6.8)***

*Note: * p < 0.10, ** p < 0.05, *** p < 0.01*

For the improvement scenario, the same regressors have a significant impact on the model estimation. The positive coefficients confirm the results of the interval regression in the status quo scenario. The mean willingness to contribute labor is estimated at 51.2 man-days yearly, with 95% CI [45.4; 56.9] and a robust standard deviation of 2.9.

3.4 Mixed survey format

In the mixed survey, respondents were first provided with the option to contribute to the Lake Tana Protection Program in the way they prefer: cash, labor, combination of both, not contribute at all. The results of these preferences are shown in table 7.

Table 5
Choice of contribution

Contribute	Frequency (%)
Cash	25 (24)
Labor	58 (56)
Mixed	18 (17)
Not contribute	3 (3)

a. Mixed survey – cash

For a limited sample size (n=25) only very strong relationships are demonstrable. However, running the interval regressions on the sample doesn't give enough evidence to reject the null hypothesis of all zero value regressors. Mean willingness to pay for the status quo scenario of the sample is 459.8 ETB yearly, with 95% CI [355.1; 564.4]. For the improvement scenario the mean WTP is estimated at 891.9 ETB per year, with 95% CI [651.1; 1132.8]. The wider intervals result from the small sample size, otherwise these results are similar to the regular willingness to pay format.

b. Mixed survey – labor

The results from the mixed – labor contribution show that the average willingness to contribute labor is at 28.9 man-days in the status quo scenario, 95% CI of [25.8; 31.9]. In the improvement scenario people or willing to contribute 46.7 man-days on average, with a 95% CI of [41.9; 51.5].

c. Mixed survey – combination

Respondents who stated to be willing to contribute to the Lake Tana Protection Program through a combination of cash and labor were given an open-question to compose their willingness to contribute bundle. The results are shown in Table 8. The combination in terms of cash was composed from the cash to labor (and vice versa) ratio that resulted from the WTP and WTCL surveys.

Table 6
Summary of results from the mixed survey

		Status quo Mean	**Improvement** Mean
Cash		459.8 ETB	891.9 ETB
Labor		28.9 MD	46.7 MD
Mixed	Combination	391.7 ETB + 48.1 MD	855.6 ETB + 65.6 MD
	Combination in terms of cash*	1042.2 ETB	1835.0 ETB
	Combination in terms of labor**	77.1 MD	122.9 MD

*Note: * Status quo: 1 MD = 440.9/32.6 ETB, Improvement: 1 MD = 764.4/51.2 ETB. ** Status quo: 1 ETB = 32.6/440.9 MD, Improvement: 1 ETB = 51.2/764.4 MD.*

4. Discussion

The results from the cash and labor surveys indicate that the WTP and WTCL respectively vary in logical ways. For one, the cash survey indicated a higher WTP when a household has more income, both in the status quo and the improvement scenario. In the labor survey, the attendance of water hyacinth conferences positively influences the WTCL, which can be attributed to the deeper knowledge and awareness of the water hyacinth problem in Lake Tana. All in all, this supports the face validity of the contingent valuation survey. It is noticeable that the age is negatively correlated with the willingness to pay and – to lesser extent - willingness to contribute labor. This result matches with the general intuition that was obtained by qualitative interviews in the study-area. Since the youth is more involved in the water hyacinth harvesting programs and is often more connected to the (social) media, it seems that they developed very serious concerns about the future of Lake Tana and are more committed to restoring the ecosystem balance. The main conclusion from the mixed survey can be drawn from the preference question. Respondents were significantly more inclined to contribute in terms of labor than the other options. With the mixed survey it was found that respondents deliberately opting to contribute in terms of cash money have a slightly higher mean WTP. However, the small sample doesn't provide reliable evidence.

Including a mixed survey format provided useful insights. First of all, it allowed to verify the results in a realistic market situation where customers have the option to contribute in any way possible. All beneficiaries of a water hyacinth-free Lake Tana have the option to contribute to the current problem in terms of labor, to donate money for research/machines, to combine these previous options or not to contribute in any manner. Secondly, the total value of the bundles that were stated by people choosing for the combination option were much higher than the values obtained in the regular cash and labor formats. Different factors may underlie these results; Firstly, respondents may have misunderstood the combination question and thus consequently overstated their willingness to contribute. Although the enumerators were trained, indicated to fully understand the survey design and were regularly observed while conducting the survey, enumerator bias remains a limitation in the contingent valuation technique. Especially when conducting CV studies in developing countries (like Ethiopia) it is advised to elaborate on the issues and advices reported by Whittington (1998, 2002) (eg. Test whether the assumptions that the researcher made are correct, train the enumerators, create a clear

hypothetical scenario, *etc.*). However, it remains that open-ended elicitation questions are more sensitive to enumerator bias than close-ended questions. Another potential explanation for the results of the mixed contribution can be related with anchoring bias. In the cash and labor contribution surveys, the dichotomous question preceding the willingness to contribute question in terms of polychotomous intervals may have caused this anchoring effect. By presenting some monetary value or some amount of man-days to contribute, respondents may have been biased to adjust their true willingness to contribute in the direction of this value. In this study, this would imply that the results obtained in the open-ended mixed contribution format are a closer representation of the true value of water hyacinth eradication around Lake Tana with the studied sample. Alternatively, open-ended questions have given evidence to significant overstatement of the actual willingness to pay (Green et al., 1998). Open-ended questions result in increased uncertainty and subsequently in biased statements. Moreover, Ian J. Bateman et al. (1995) found that positive interests in the conservation of a good may induce strategic overstatement if the respondent believes that this would influence the provision of such a good. While conducting this study, qualitative interviews confirmed that the people in the study-area strongly rely on the natural resources brought forth by Lake Tana and are severely (negatively) affected in their livelihood by the ecosystem disservices. During qualitative interviews the hopelessness towards the infestation was translated into answers such as: "We will do everything to get rid of *Enboch* ('water hyacinth' in Amharic)". It is this attitude that may cause this (strategic) overstatement. Additionally, the unrealistic prospect of completely eradicating water hyacinth on Lake Tana may cause a willingness to contribute that is influenced by a short term view. Respondents may be convinced that profound sacrifices of time/money now will solve the problem within a short time period, leading to unrealistically high contributions if the results would be expanded to medium to long term (> 5 years). In this light we can compare our findings with the one-time payment for eradication that was studied with urban households living in Bahir Dar city by Tesfa (2019). The latter found a mean WTP of 1,011 ETB for water hyacinth control, which is defined as 'cleaning of water hyacinth from the Lake'. This corresponds to the improvement scenario in this study. Correspondingly, this value would imply only 1 to 2 yearly monetary payments, what could confirm the intuition of unrealistically high contributions. However, because of the difference in target groups (urban dwellers vs. direct agricultural stakeholders), this assumption cannot be confirmed.

Few other factors must be taken into consideration in interpreting the results of this study. First of all, one must understand the cultural context of making contributions to the state. In Ethiopia, the practice of contributing free labor to the state is a longstanding tradition. As

opposed to other regions, community work is generally widely accepted within the study area. Secondly, the skewed male sample introduces a gender bias. Considering the fact that male household members are obliged to contribute to the ongoing community actions, their willingness to contribute is expected to be higher than those of female household members. However, in opting for contribution as a household for the payment scenario's, which is typically a male's decision in the study area, it was intended to reduce the influence of this sampling bias. Thirdly, the influence of the relatively small sample must be highlighted. This results in higher variance and wider confidence intervals for WTP and WTCL.

With regard to the cash constraint that was assumed, mixed evidence was observed. Firstly, from the choice of contribution in the mixed survey, it could be interpreted that there is a cash constraint, which impedes on the actual value of the ecosystem to the farmers. On the other hand, the ratio that was observed as a result of the cash format and the labor format can be interpreted as indicating otherwise. For the status quo, it was found that 1 man-day is worth 13.52 ETB and for the improvement scenario this ratio was 14.93 ETB/MD. Similar to Tilahun M. et al. (2015), the convergence validity can be tested through using the public employers' minimum wage to make the conversion. Public sector employees are the largest group of wage earners in the country, according to the 2017 Country Reports on Human Rights earning a minimum wage of 615 ETB monthly (U.S. Department of State, 2018). When taking into account the fact that one month entails 20 to 23 workable days on average, the value of one working day lies within the range of 26.7-30.8 ETB. Thus, the ratio's that were obtained through the study cannot be considered as reflecting the value of public employers' minimum wages, what could imply a significantly skewed valuation of time. However, when considering the poverty income level of 315 ETB (U.S. Department of State, 2018), a ratio of 13.7-15.8 ETB is obtained. Realistically, the latter is a more accurate estimation of the situation in agricultural communities on Lake Tana shores. It can be concluded that simply assuming that a cash constraint will influence results in developing countries, may not be realistic. Especially when the livelihood is directly and drastically affected by the EDS, measured WTP may reflect pragmatic value.

Having evidence of the validity of the survey responses, one can extrapolate these findings on the broader population. The study-area consists of three kebeles in three different woredas. Therefore, the results are extrapolated on all households in the infested kebeles of these three woredas. In Dembiya seven kebeles are infested (9,834 households), in Gondar Zuria five kebeles are infested (11,129 households) and in Dera one kebele is infested (2,051 households). In total 23,014 households are thus affected in these three woredas. Extrapolating

the values of the WTP and WTCL, taking into account the percentage of zero responses, results in aggregative yearly contributions as shown in table 9.

Table 7
Aggregated yearly willingness to contribute

	Status quo	Improvement
Willingness to pay (Ethiopian Birr)	9,766,365 (or € 317,678*)	16,932,206 (or € 550,767*)
Willingness to contribute labor (man-days)	750,256	1,178,317

* Based on conversion rate in may 2018

The numbers depicted in table 9 give an indication of the willingness to contribute of some of the direct users of the ecosystem services provided by Lake Tana. It is important to stress that this is not the overall total benefit for a Lake Tana without water hyacinths. Only three out of five infested woredas were considered in the extrapolation. Moreover, contingent valuation studies often describe the influence of distance to the environmental good on the willingness to contribute, implying additional (but diminishing) willingness further away from the lake (Schaafsma et al., 2012; Yao et al., 2014). With 2 to 3 million people living in the Lake Tana Biosphere Reserve and the importance of the ecosystem services the Biosphere provides, many more stakeholders contribute to the total benefits of eradicating the water hyacinths. It is clear that the communal economic weight of the infestation is at a level where action is to be undertaken.

In Africa, biological control is a widely applied solution to infestations . Among other water bodies in Eastern Africa, the Lake Victoria basin suffered a severe infestation from 1989 to 2001, the cost of which was estimated in the order of billions of dollars (Mailu, 2001). Eventually biological control was responsible for the decline of this infestation (Albright et al., 2004). Biological control has been successful in other African countries, case studies of Lake Chivero (Zimbabwe), White Nile (Sudan), Southern Benin confirmed its potential (De Groote et al., 2003; Irving & Beshir, 1982). In Benin, the biological water hyacinth control was estimated to have outweighed the costs with a 124:1 ratio (De Groote et al., 2003), in South Africa the benefit to cost ratio was calculated at 4.2:1 (Law, 2008).

From the ES-EDS perspective, the invasion process of alien plants is to be managed in four sequential strategies: identification, protection, mitigation and adaptation (Vaz et al., 2017). For Lake Tana, the severity of the problem observed and the results of this socio-economic study leaves no strategic solution except for the last in line: *adaptation* . The water

hyacinth is in Lake Tana to stay. Local communities are to adjust to the newly defined relation between the ES and EDS. The socio-economic impact on local smallholders that was assessed in this study not only justifies potential management expenditures on the control of the weed, but can also justify infrastructure investments to benefit from the occurrence of water hyacinth. Cases in Bénin and Lake Victoria (Güereña et al., 2015; Ogutu-Ohwayo et al., 2016; Roux, 2019), where water hyacinth was initially experienced as 'an ecological disaster', now give evidence of creating added value from water hyacinth. Water hyacinth - in Bénin promoted to 'green gold'- can be utilized to generate biogas and fertilizers. With regard to sustainable ecosystem and resource management, providing the necessary equipment for processing water hyacinth into a productive resource in newly defined business processes may be the strategically opportune decision.

5. Conclusion

We found that the assumption of low valuation of time might not stand when the subject of valuation directly influences the livelihood. Moreover, local conferences and awareness of the water hyacinth invasion has a positive influence on the willingness to contribute. Which implies that governments could promote communal harvesting of water hyacinth by ensuring the provision of qualitative local conferences, rather than punishing absence with fines as it is today. The water hyacinth infestation - which originates from broader issues with water management - and its consequences on the economic value the Lake Tana ecosystem, require an integrated approach. Integrated in the sense of potential solutions: controlling the weed and providing sustainable and economically desirable destinations. Integrated in the sense of the acting parties: the people of Lake Tana, private initiatives (e.g. The Global Coalition for Lake Tana Restoration), research bodies, but also active governmental intervention. Integrated in the sense of treating not only the consequences, but also addressing the catalysts of the aggressive outbreak, pleading for an integrated water and waste management policy. Lastly, integrated in the sense of multidisciplinary research on the water hyacinth issue in the Lake Tana Biosphere reserve. With ecosystem valuation being scarce, and valuation exercises often limited to the valuation of just one or a few ecosystem services, the stakeholder perspective presented in this research provides noticeable advantages. Instead of time and expertise intensive approaches of identifying ecosystem services before pinning separate value to each of them, the stakeholder-centered perspective offers the opportunity to assess an ecosystem's value, based on the sum of benefits every stakeholder perceives. In this study, only the impacts on farmholders were researched, studies on the (potential) impact on other actors is advised for a comprehensive

assessment of the total benefits the water hyacinth eradication/control entails. Moreover, using different valuation methods (choice experiments, travel cost methods, *etc*.) would enhance a complementary and comprehensive overview. Further research is required on the economic damage of the water hyacinth infestation on the ecosystem services provided by Lake Tana and - by extension - the overall economic value of the Lake, for justifiable and sustainable ecosystem management. After all, as Ian J Bateman and Willis (2001) stated: "What we need to assess and conserve is the structural and functional value of 'healthy' evolving ecosystems."

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7. Appendix

A. Full survey

ITEM ONE: MIXED WTP

QUST ID_____

This survey is designed to examine the trade-offs between agriculture and the ecosystem services provided by Lake Tana. More specifically the relation of the E. Crassipes or water hyacinths to the ecosystem services, and its influence on agriculture. Your responses are completely confidential.

The importance to you of the Lake Tana basin (Q12): explain how Lake Tana is important to your livelihood

	PERSONAL REASONS FOR VALUEING LAKE TANA	NOT IMPORTANT 1	SLIGHTLY IMPORTANT 2	MODERATELY IMPORTANT 3	IMPORTANT 4	VERY IMPORTANT 5
12A	Crop production (irrigation)	❍	❍	❍	❍	❍
12B	livestock production	❍	❍	❍	❍	❍
12C	Recreation	❍	❍	❍	❍	❍
12D	Religion	❍	❍	❍	❍	❍
12E	Fishing	❍	❍	❍	❍	❍
12F	Transportation	❍	❍	❍	❍	❍
12G	Tourism(offarm center)	❍	❍	❍	❍	❍
12H	Mining	❍	❍	❍	❍	❍
12I	Other:	❍	❍	❍	❍	❍

13) Have you ever – during one of the activities above – experienced problems due to the effects of the water hyacinth?

1) YES 2) NO

14) if yes, which one? …….. (Choose from 12A to 12i)

INTERVIEWER –PLEASE REFER THE ATTACHED CARD

ASSUMING THAT YOU ARE SENSITIVE TO THE PROBLEMS WE EXPLAIN, PLEASE RESPOND TO THE FOLLOWING QUESTIONS;

_____TRQ) In which way are you willing to contribute to counter water hyacinth infestation

1) Labor 2) Cash money 3) Mixed 4) Not willing to contribute

--->>>>> If your choice is labor Go to Section A questions, if Cash money Go to Section B questions, If Mixed go to Section C, If not willing for any of them Go to Section D question.

SECTION A: LABOR WILLING

STATUS QUO SCENARIO

Given the above description let us assume you are willing to contribute labor to save Lake Tana……

15. Would you agree with the Lake Tana protection program if you would have to contribute 20 **man-days** yearly in order to keep water hyacinth infestation constant at current levels rather than

having the infestation spreading and covering more surface of the Lake and Wetlands, thus keeping your farming productivity at the current level? (Choose one)

1) YES 2) NO

16. What is the maximum your household would contribute in **man-days** yearly in order to keep water hyacinth infestation constant at current levels rather than having the infestation spreading and covering more surface of the Lake and Wetlands, thus keeping your farming productivity at the current level?

1) Zero MD 2) 1-10MD 3) 11-20MD 4) 21-30MD 5) 31-40MD 6) >40MD

16B) If above 40 man-days, how many man-days you do you want to be involved

Answer Question #17 only if you indicate to not contribute any, otherwise go to Question #18.

17. What was the main reason to pay 0 days? (Check any one or more)

1) I don't encounter problems due to water hyacinths
2) I don't feel responsible for this
3) Keeping it at current levels is not enough
4) I am on a limited budget and cannot contribute
5) Other: ……..

IMPROVEMENT SCENARIO

Assume that through biological or chemical control programs, it is possible to remove the water hyacinth infestation completely.

18. Would you agree with the Lake Tana protection program if you would have to contribute 40 **man-days** yearly in order to completely remove the water hyacinth infestation permanently, and improve the farming productivity accordingly?

1) YES 2) NO

19. What is the maximum your household would contribute in **man-days** yearly in order to completely remove the water hyacinth infestation permanently and improve the farming productivity accordingly?

1) Zero MD 2) Less than 20MD 3) 20-30MD 4) 31-40MD 5) 41-50MD 6) 51-60MD 7) > 60MD

19B) If above 60 man-days, how many man-days do you want to be involved

Answer Question #20 only if you said you would not contribute any days.

20. What was the main reason to contribute 0 days? (Check only one)

1) I don't encounter problems due to water hyacinths
2)I don't feel responsible for this
3)I am on a limited budget and cannot contribute
4)Other:

SECTION B: CASH MONEY WILLING

STATUS QUO SCENARIO

Given the above description let us assume you are willing to contribute Cash money to save Lake Tana……

15. Would you agree with the Lake Tana protection program if it reduced your income **each year** by 500 ETB in order to keep water hyacinth infestation constant at current levels rather than having the infestation spreading and covering more surface of the Lake and Wetlands, thus keeping your farming productivity at the current level? (Check one)

1) YES 2) NO

16. What is the maximum your household would pay **each year** in order to keep water hyacinth infestation constant at current levels rather than having the infestation spreading and covering more surface of the Lake and Wetlands, thus keeping your farming productivity at the current level?

1) 0 ETB 2) 0-100 ETB 3) 101-300 ETB 4) 301-400 ETB 5) 401-500 ETB 6) 500-750 ETB 7) >750 ETB

16B) If above 750 ETB, how much ETB do you want to contribute

Answer Question #17 only if you indicate to pay nothing, otherwise go to Question #18.

17. What was the main reason to pay 0 ETB? (Check one or more)

1)I don't encounter problems due to water hyacinths
2) I don't feel responsible for this

3) Keeping it at current levels is not enough
4) I am on a limited budget and cannot contribute

5) Other: ……..

IMPROVEMENT SCENARIO

Assume that through biological or chemical control programs, it is possible to remove the water hyacinth infestation completely.

18. Would you agree with the Lake Tana protection program if it reduced your income **each year** by 1000 or more ETB in order to completely remove the water hyacinth infestation permanently, and the farming productivity improves accordingly?

1) YES 2) NO

19. What is the maximum your household would pay **each year** in order to completely remove the water hyacinth infestation permanently and the farming productivity improves accordingly?

1) 0 ETB 2) 0-250 ETB 3) 251-500 ETB 4) 501-750 ETB 5) 751-1000 ETB 6) 1001-1500 ETB 7) >1500 ETB

19B) If above 1500 ETB, how much ETB do you want to contribute

Answer Question #20 only if you said you would not pay anything.

20. What was the main reason to pay 0 ETB? (Check only one)

1) I don't encounter problems due to water hyacinths
2)I don't feel responsible for this
3)I am on a limited budget and cannot contribute

4)Other:

SECTION C: MIXED COMBINATION OF LABOR AND CASH MONEY WILLING

STATUS QUO SCENARIO

15. What is the maximum your household would contribute to the Lake Tana protection program in **a combination of man-days and cash money** yearly in order to keep water hyacinth infestation constant at current levels rather than having the infestation spreading and covering more surface of the Lake and Wetlands, thus keeping your farming productivity at the current level?

Man-days and ETB

IMPROVEMENT SCENARIO

16. What is the maximum your household would contribute to the Lake Tana protection program in a **combination of man-days and cash money** yearly in order to completely remove the water hyacinth infestation permanently and the farming productivity improves accordingly?

Man-days and ETB

SECTION D: REASONS FOR NOT WILLING TO PAY

15. What are your reasons not to contribute to counteract water hyacinth infestation in Lake Tana

1) I don’t encounter problems due to water hyacinths

2)I don’t feel responsible for this

3)I am on a limited budget and cannot contribute

4)Other:

PERSONAL INFORMATION

This information is for statistical purposes only and is completely anonymous.

1. Sex of the head (reporter) 0) MALE 1) FEMALE

2. Age: _____ years

3. Location of the household's farm plot/s: 1) around LT 2) Far from LT

Woreda Kebele

4. Is the household head the owner of the farm plot/s

1) YES 2)NO

5. Farm experience of the household head

1)0-5 years 2)6-10 years 3)11-20 years 4)Over 20 years

6. Highest education of the household head?

1) Can't read and write

2) None formal Education

3) Grades attended (1---24 years)

7. Have you participated/attended local conferences about the water hyacinth infestation?

1) YES 2) NO

8. What is the main type of agricultural activity in your household?

1) CROP PRODUCTION 2) LIVESTOCK 3) MIXED

kind of crop/livestock: …….

9. What is the estimated average annual farm income of the household? (ETB)

10. What is the estimated average annual farm income of the household? (ETB) in category

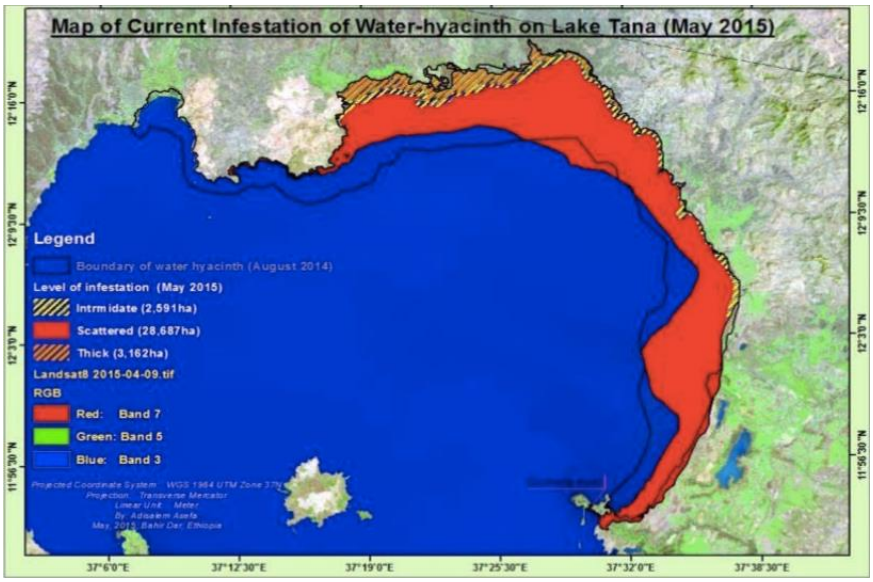
1) Less than 10000 ETB 2) 10000-25000 ETB 3) 25000-50000 ETB 4) > 50000 ETB

11. What is the estimated average annual off-farm income of the household? (eg fishing, craft work, …)

1) Less than 5000 ETB 2) 5000- 10000 ETB 3) 10000-20000 ETB 4) > 20000 ETB

B. Information Card

The water hyacinth, endemic to South America, was introduced as an ornamental in Africa decades ago. Known as an invasive aquatic weed, the Regional Environmental Bureau named E. Crassipes as the **most dangerous weed challenging the Lake Tana ecosystem** in 2011. Studies claim that the infestation is still expanding today. The picture below shows the status of Lake Tana regarding E. Crassipes infestation in may 2015.



The water hyacinth is known to hinder agricultural activities.

- **Livestock farming is affected** because the weed devastates native species, including grasses, thus reducing food availability for the livestock and invading the grazing lands.
- **Crop production is affected** since mats of water hyacinths cover rice fields in times of flooding. In infested areas farmers state that the land becomes more difficult to plough. The last years, farmers have to spend extra resources on cleaning up their farmlands.

Over the last years, multiple efforts to remove water hyacinths have been undertaken. However, after mechanical removal of the water hyacinth, it takes only months before the surface is covered again.

Picture of water hyacinths:

C. Picture of water hyacinth removal campaign