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DETERMINANTS OF MANUAL CONTROL OF WATER HYACINTH EXPANSION OVER THE LAKE TANA, ETHIOPIA

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ABSTRACT

Water hyacinth is an exotic freshwater weed damaging wetland resources over the Lake Tana basin, Ethiopia. Different measures, including manual labour and harvesting machinery are in use to reduce its damage and expansion. Yet, the invasion of the weed appears expanding its scope across the wetlands of the Lake. This paper presented the study made to identify determinant factors affecting manual control of water hyacinth expansion over the Lake wetlands. It tried to analyse the expansion trend of the water hyacinth and community efforts to control its extension. Data were gathered from questionnaire surveys, group discussions, interviews and field observations. Descriptive statistics and binary logistic regression were used for data analysis. The study revealed that the water hyacinth cover in the Lake's wetland increased from ≤10, 000 ha in 2011 to over 50, 000 ha in 2017. Wetland terrain, water depth, food availability, farming time, employment and government support were found significantly influencing the manual control practices of households. Hence, government support must increase to motivate people involvement in manual weed removal campaigns. Micro-relief maps and floating boats need be readily available to help participants easily identify risky terrains and expand the physical weed removal into the deeper waters.

Key Words: Water hyacinth, Invasive weeds, Manual control, Wetlands, Lake Tana, Ethiopia

INTRODUCTION

Water hyacinth (*Eichhornia crassipes*) is an attractive freshwater flower widely distributed across the world. But it is a renowned menace to aquatic and freshwater resources almost all over the world (Holms, Plucnett, & Pancho, 1991; Villamagna & Murphy, 2016; Pandurang & Sagar, 2017; Agidie, Samuel, Adugnaw & Mehari, 2018). Presently, it is becoming somber problem in many countries of Africa (e.g. see De Groote, Ajuonu, Attignon, Djessou & Neuenschwaander, 2003; Kateregga & Sterner, 2007, 2009; Dagno, Lahlali, Diourte & Haissam, 2012).

Water hyacinth in Ethiopia was first introduced in the Rift Valley Lakes Region as a decorative plant during the 1950s and then distributed to the Highland Lakes through time (Firehun, Struike, Lantinga & Taye, 2014; Tegene & Ayele, 2014). Since then, it emerged to be among the ten top ecologically risky aquatic flowers in the country. It has inflicted adverse impact on social, economic and livelihood condition of the people and development projects in the Rift Valley Lakes Region (Mengistu, Unbushe & Abebe, 2017).

Recently, the appalling incident of the weed is observed on the largest Lake of the country (Lake Tana) and its surrounding wetlands (Agidie et al., 2018). Its existence over the Lake's wetlands was first observed in 2011 at the mouth of River Megech; covering some 80 - 100 ha lands along the northern rims of the Lake (Tewabe, 2015; Asmare, 2017). The invasion has then severely expanded into the north-eastern catchments of the Lake and covered almost 15% of the northern parts of the Lake's coastal lands (Asmare, 2017). According to Tewabe (2015), the area coverage of the water hyacinth in 2011 was ≈80 - 100 ha. A year later, it has increased to somewhat 20,000 ha and rose to 50,000 ha in 2014 (Anteneh, Tewabe, Addisalem, Abebaw, Bifta & Yitayew, 2015).

Recent evidences remark still that the invasive weed is distributed to almost all the northern tip littoral zones of the Lake Tana basin and is causing grave damage on the adjacent coastlands. It is already posing significant threat on livestock feed sources, farmland sizes, native plant species, fishing activities, water quality, crop production, recreation (swimming), and grazing pastures. It is greatly impacting the balance of the local ecology and biodiversity. For instance, it is altering the growth and reproduction of the native flora and fauna diversity through reducing sunlight penetration, nutrient supply, oxygen availability and water access to native aquatic organisms. Agricultural input depositions and residues transported from upslope areas are intensifying the weed expansion (Asmare, 2017; Tewabe, Asmare, Zelalem & Mohamed, 2017).

Water hyacinth impacts crop production through covering rice fields by its mats. It causes the compaction of soils on farmlands. The heaps of harvested water hyacinth occupy large spaces and make ploughing difficult. Clearing the farmlands from water hyacinth and land preparation demands more labour and time which is difficult to cover by the poor farmers. Tewabe et al. (2017) noted that about 19 manual workers are required to clear the water hyacinth from 0.25 ha lands. The collected weed heaps then left the farmlands fragmented and complicated to manage. Water hyacinth also affects livestock rearing in the lake adjacent villages through reducing the growth of hippo grasses (water submerging grasses) that are used for feeding cattle (Tewabe et al., 2017).

Water hyacinth can deeply distress fish production efforts and fishing performances through narrowing the fish catch locations and the fish holding rates (Makhanu, 1997). This is because water hyacinth mats block the movement of the fishing boats and the fishing nets. It sometimes damages the fishing boats and the 'gill nets' that further demand extra labour, time and money for repairing and maintenance. Losses of fishing tools and instruments are also reported in past literatures. Water hyacinth thus not only diminishes the fish population but also the efficiency of fish production (Asmare, Sewmehon, Tewabe & Mihret, 2016; Tewabe et al., 2017).

The weed is very notorious and can cover the whole Lake in a few years' time if immediate control measures are not taking place. The influx is mainly severing in the eastern and western parts of the Demebia District, around Gorgora, SeravaDavilo and Woyna Tana villages. In understanding the severity of the problem, the local community in collaboration with the local government and other stakeholders made several efforts to remove the invasive alien weed using manual labour. A tremendous amount of human labour (≈40,000 farmers in 2013) was organized by the surrounding community and the local government to control the expansion of the invading flower. Nevertheless, the eradication efforts and systems were having their own problems related to harvesting time and use of only manual labour. Absence of proper soil conservation practices on the upper watersheds, expanded cultivation in the wetlands bordering the Lake, weather variability and lack of firm concern and strict focus among the concerned stakeholders have also constrained the weed removing efforts of the local community (Anteneh et al., 2015; Asmare, 2017). Lack of knowhow on the life scale of the weed, poor storage of the harvested weeds and the spread of the weed fragments to adjacent waters through disturbances and waves make less effective the manual control efforts of the people (Tewabe et al., 2017).

With due consideration of the problems inflicted by the water hyacinth, several research studies cited elsewhere above (e.g. Anteneh et al., 2015; Tewabe, 2015; Asmare et al., 2016; Asmare, 2017; Tewabe et al., 2017; Agidie et al., 2018) were conducted at different times. Most of these studies focused on the weed expansion and on its potential impacts. But, why the manual effort of the community fails to succeed in reducing the expansion of the invasive plant species is not well assessed.

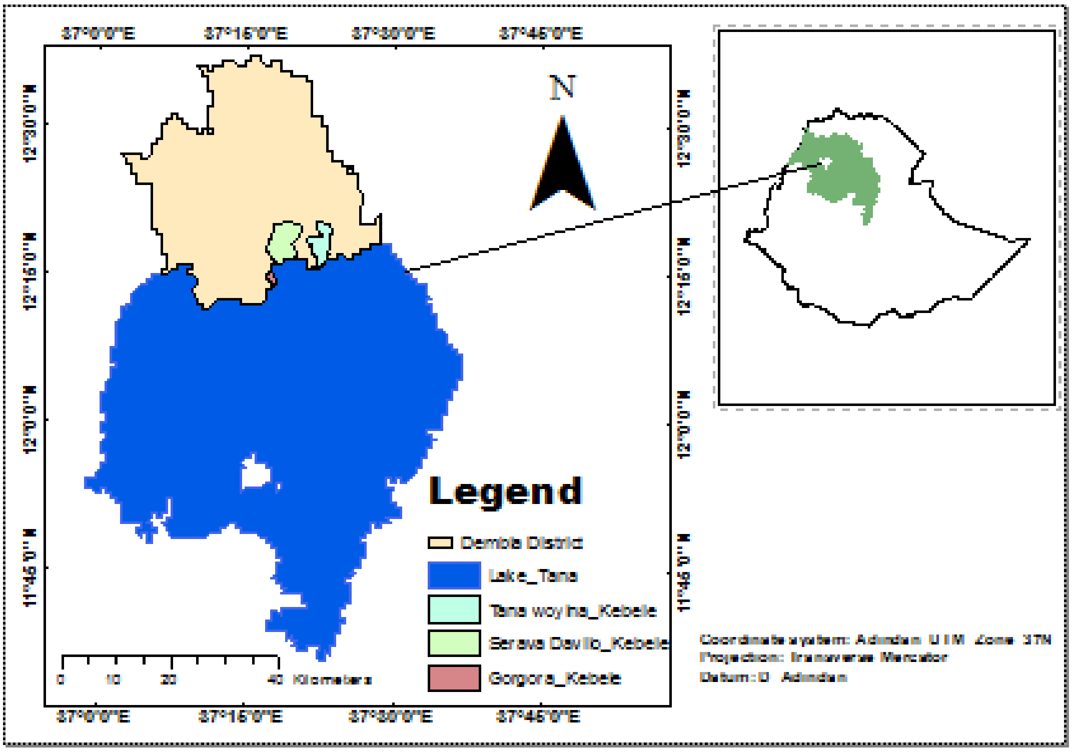
This study identified the factors influencing the manual control of water hyacinth expansion over the Lake Tana wetlands, Ethiopia. In the course of the assessment, the study tried to analyze the trend of the weed expansion and the efforts made by the community to control its expansion.

THE STUDY AREA AND METHODS

Geophysical Setting of Lake Tana

Lake Tana is geographically found in the north –western part of Ethiopia between $10^0 58'$ -12^0 47 ' N latitude and $36^0 45$ ' - $38^0 14$ ' E longitude (Figure 1). It is the largest freshwater lake in the country, contributing about 50% of the water resources of the nation. The north-south maximum length is 90 km and the east-west width is 65 km. The maximum depth of Lake Tana is 14 m, with mean of 9 m. The lake is located at a higher altitude (at 1840 m asl); covering a surface area of 3,200 km^2. Hence, it is the highest lake in Africa in terms of altitude compared to Lake Victoria which is located at 1134 m asl (Abitew, 2008; Goshu & Aynalem, 2017).

Figure 1: Location map of the study area



The Lake's Basin is physically perched on a horizontal topographic high within the Ethiopian plateau (Chorowicz, Collet, Bonavia, Mohr, Parrot & Kome, 1998). The entire basin geology is related to the Afar mantle plume uplifted dome (Pik, Marty, Carignan & Lave, 2003). The upper landscape is covered by recent volcanic rocks of both the Tertiary and Quaternary ages (Chorowicz et al., 1998). Uplift, subsidence, block fault, recent volcanism and organic rich alluvial sediment depositions at the center characterize the basin. The Lake's basin in addition is characterized by complex lithologic and tectonic features forming the source of the Blue Nile River (Seifu, 2013).

Lake Tana is fed by many streams and a few large rivers (Goshu & Aynalem, 2017). Over 60 rivers and streams draining from the nearby watersheds form complicated hydrologic networks within the Lake's Basin. The most important of these rivers are Arno-Garno, Dirma, Gelda, Gilgel-Abbay, Gumara, Megech and Ribb (Getahun & Dejen, 2012).

The soils of the islands, peninsulas and surrounding wetlands and dry uplands of the Lake are dominated by Nitosols, Luvisols and Vertisols. Flood plains of Dembia and the river mouth deltas of Dirma and Megech are dominated by alluvial deposits. These soils are continuously renewed and often cultivated during the dry season following the retreating of the Lake's water (Goshu & Aynalem, 2017).

The annual climate of the Lake Tana basin is divided into distinct rainy and dry seasons. The northward movement of ITCZ is the major source of rainfall from June to September; creating about 90% of the annual rainwater (Uhlenbrook, Mohamed & Gragne, 2010). The mean annual rainfall is roughly 1280 mm (Setegn, Srinivasan & Dargahi, 2008) and the mean annual temperature in the basin is about 22^0C.

The land use in the Lake Tana basin is predominantly agricultural. Reverine shrubs, swampy grasses and floating-leaved species including the water hyacinth are noted as the most important submerging plants occurring in the Lake’s immediate environment (Getahun & Dejen, 2012).

Socioeconomic Setting of the Study District and Lake Tana Basin

According to CSA (2013) projection, the total population of the study District (Dembia District) in 2017 was 326,719; of which 165,502 were males and 161,217 females. Crop and livestock farming, fishing, tourism, small and medium-scale business (trade and industry) form important economic setting in the area (Abitew, 2008).

Lake Tana and its islands comprise impressive attraction of natural and cultural settings. The main natural attractions of tourist value are the forested peninsulas and islands, the birds as well as the hippopotamus. In addition to the great natural attractions, Lake Tana is also endowed with various historic heritages. The region hosts ancient manuscripts and artefacts from the old emperors of the Ethiopian Empire (BOCTPD, 2011).

RESEARCH METHODOLOGY

Research Design

Concurrent mixed methods research design composed of quantitative and qualitative approaches was employed for the study. This means that both quantitative and qualitative data were collected simultaneously and the results were embedded during the analysis. The major objective was to understand the results of quantitative as is confirmed by the qualitative results. Biophysical, demographic and socioeconomic data were collected and analyzed quantitatively while people’s perceptions, beliefs and attitudes were collected and analyzed using qualitative research methods.

Sampling Technique and Sample Size Determination

Lake Tana is surrounded by various Districts. Some of these are Dera, Libo-Kemkem, Fogera, Gondar Zuria, Dembia, Takusa, Alefa, Liben, Chimba, and Bahir Dar Zuria. Of these, Dembia District was purposively picked as the target site of the study due to the severity of water hyacinth expansion and its proximity to the researchers. The District has 40 rural and five urban (a total of 45) Kebele Administrations (KAs, lower government units). From these, one Urban KA (Gorgora) and two Rural KAs (Seraba-Dabilo and Woyna-Tana) were intentionally identified for the study because they were more affected by the water hyacinth compared to others**.** The total households (sampling frame) for the selected KAs were 4248. From these, 222 sample households were determined to fill the survey questionnaire with consideration of representativeness to the desired study, availability of time and financial capacity. The 222 sample households were systematically identified from a stratified list of the total households obtained from the KA offices.

Three focus groups (one in each KA) were organized for focus group discussions (FGDs). A total of 21 knowledgeable persons (seven in each KA) were purposively selected for this purpose. Nine key informants were purposively selected from Bahir-Dar University Biology Department, Agricultural Research Institute (ARI) and from the Regional Water and Land Administration Offices for additional information retrieval.

Data Collection Instruments

Both primary and secondary sources were used to generate data required for the study. The main instruments designed to collect the primary data were questionnaire, key informant interview, FGD and observation. Data using questionnaire survey were generated from the 222 households using both closed and open format questions. Issues raised were demographic, biophysical and socioeconomic characteristics of the households and variables related to determinants of manual control of water hyacinth expansion. The principal investigator and three enumerators all speaking the local language conducted the survey from April-September 2018.The enumerators were first trained how to present and explain each question to the respondents.

Discussions were made with the three focus groups organized for the purpose. They were led by the principal investigators. The occurrences, trends, impacts and controlling methods of the water hyacinth were issues raised during the discussions.

Interviews were made with nine key informants to get in-depth information about the problem. Semi-structured interview schedules were prepared for the purpose and the interviews were handled by the principal investigators.

Observations were also conducted along east-west and north-south transects at the start, during the middle and at the end of the survey time.

Methods of Data Analysis

Both quantitative and qualitative techniques were employed to analyze data. Upon completion of data collection, the data were coded edited and entered into the Statistical Package for Social Scientists (SPSS version 20) and analyzed using descriptive statistics such as frequencies and percentages. Binary logistic regression model was used to identify the factors that determine the efforts made by the households to control the expansion of the weed over the Lake's wetlands. Such kind of model is suitable when the dependent variable is dummy; where households' participation in removing the invasive weed was coded as one (1) for yes and zero (0) otherwise. The variables that determine households' participation in removing the invasive weed were grouped into demographic, biophysical, socioeconomic and institutional factors (Table 1).

Table 1. Definition of explanatory variables

Variables	Definition	Sign
Demographic variables		
Sex	1 if male; 0 otherwise	+
Age	Years	+
Marital status	1 if married; 0 otherwise	+
Education	1 if attended formal education; 0 otherwise	±
Family size	№ of household members	+
Biophysical barriers		
Type of terrain	1 if level terrain; 0 otherwise	±
Water depth	1 if shallow; 0 otherwise	±
Insect	1 if there are no dangerous insects; 0 otherwise	±
Socioeconomic factors		
Household income	Ethiopian Birr (ETB)	+
Food availability at home	1 if Yes; 0 otherwise	±
Sharing farming time	1 if sharing farming time; 0 otherwise	-
Institutional factors		
Government support	1 if Yes; 0 otherwise	+
Availability of focus	1 if Yes; 0 otherwise	+
Employment	1 if employed by government; 0 otherwise	±

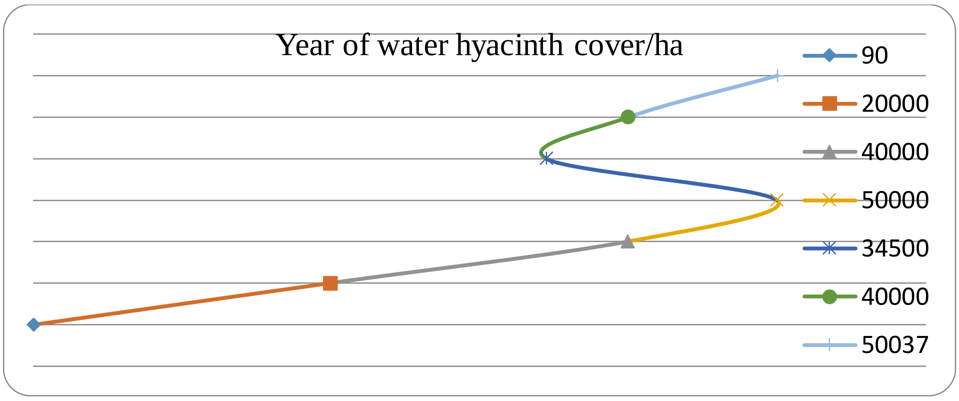
In checking the goodness-of-fit of the model, classification tables, Hosmer & Lemeshow (1989) test, Pseudo R^2 and Omnibus Tests of Model Coefficients (full model) were used. Besides, outliers and multicollinearity were assessed for the model. Multicollinearity occurs when two or more independent variables are approximately determined by a linear combination of the independent variable in the model (Quinn & Keough, 2002). In this regard, Gupta (1999) suggested that a bivariate correlation coefficient greater than 0.8 (in absolute terms) between two independent variables indicates the presence of significant multicollinearity effect.

RESULTS AND DISCUSSION

Trend of Water Hyacinth Expansion over the Lake Tana Wetlands

Data from different sources were gathered to see the trend of water hyacinth cover over the Lake Tana wetlands. Accordingly, the area covered by the invasive weed was almost ≤10, 000 ha in 2011and alarmingly increased to over 40,000 ha from 2012 to 2014 (Figure 2). As seen from the figure, there was a slight decline in the weed cover in 2015, may be due to its partial removal from 2013-2015 using manual labour campaigns as reported in Anteneh et al. (2015). The expansion trend; however, has surprisingly increased to over 50, 000 ha in 2017. This trend of weed cover is almost consistent to what is reported in previous studies (e.g. Anteneh et al., 2015; Asmare, 2017; Dejen, Anteneh, Vijverberg, 2017; Tewabe et al., 2017).

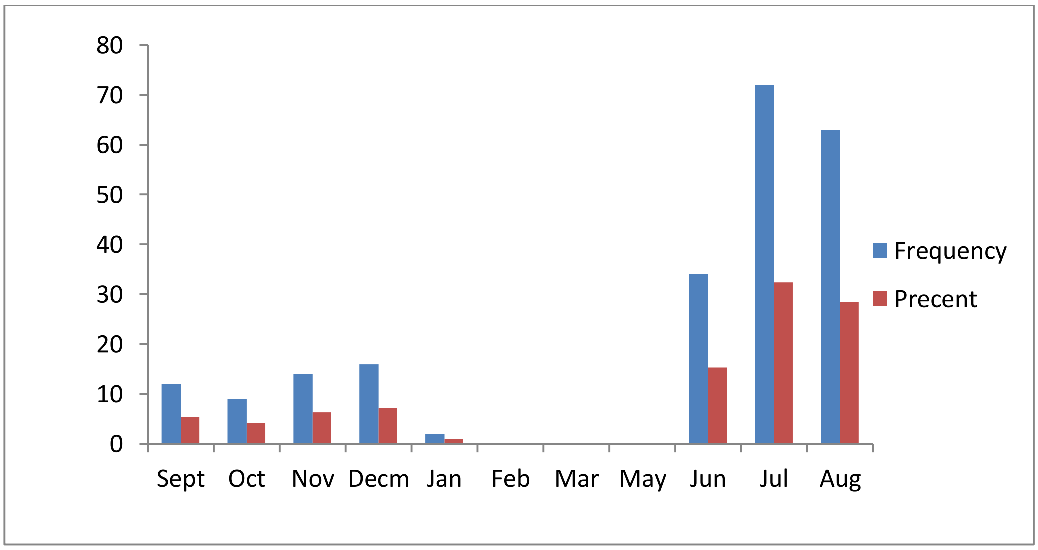
Figure 2: Trend of water hyacinth expansion (2011-2017).



As observed in the field, the weed cover is most common at the mouths of the rivers and at the immediate margins of the Lake where untreated wastewater and eroded chemical joins the Lake and where water quality deteriorates while nutrient load and availability relatively increases. Such conditions favour water hyacinth to flourish as reported in many studies (e.g. Anteneh et al., 2015).

The study revealed that the weed prevails in all of the months; however, June, July and August favoured the greatest expansion (Figure 3). According to the perceived report of respondents, months from September to December face moderate water hyacinth cover whilst the months with the least invasions are from January to May.

Figure 3: Perceived water hyacinth infestation by month.



Water Hyacinth Controlling Efforts

Information on this issue was compiled from FGDs, key informant interviews and office reports. Accordingly, it was checked that KAs, District offices, Zones, Regional and Federal governments and NGOs participated in the water hyacinth controlling efforts during the past eight years. The roles of the KAs were mobilizing the local people during the water hyacinth removal campaigns through the creation of water hyacinth forums and panel discussions. The District administrations participated by accessing logistic requirements (e.g. vehicle transport) during the weed harvesting campaigns. The Regional Government played role by exposing the danger to the public through government Mass Media. Various meetings and conferences, panel discussions, pamphlet papers and brochures were also prepared by the Regional Government Bureaus as confirmed by key informants. Office sources from the Environmental Protection, Land Administration and Use Bureau of Amhara Region (EPLAUBAR), Ethiopia, the Regional Government had allocated ETB 3,000,000 in 2018 for buying machinery that can help in harvesting the water hyacinth. As data obtained from the mentioned Bureau, 212,779; 45,097; 242, 086; 98,755 and 184,161 people were mobilized to manually remove the water hyacinth from the Lake's wetlands in five consecutive years (from 2013-2017, respectively). The labour mobilizations were also mentioned in the past studies (e.g. see Anteneh et al., 2015; Asmare, 2017). However, the outcomes were not found effective and satisfactory. Most of the people mobilized to harvest the weed were farmers who some of them complained forced by local authorities as to informal sources.

Determinants of the Manual Control Practices of the Water Hyacinth Expansion

The binominal logistic regression model was employed to identify determinant variables affecting manually controlling practices of the water hyacinth expansion over the Lake Tana wetlands. Fourteen predictor variables were selected to explain the dependent variable. Out of the total predictor variables, seven were significant at 1%, 5% and 10% probability levels (Table2). The omnibus test of model coefficients has a Chi-square value of 67.689 ($P < 0.001$) on 14 degrees of freedom indicating that the predictor variables selected have a high joint effect in predicting the dependent variable and hence the null model has improved. The Hosmer-Lemeshow goodness of fit statistic ($P = 0.340$) also indicated the model is fitted. The predictive efficiency of the model showed that out of the 222 sample households included in the model, 179 (80.6%) were correctly predicted. Multicollinearity among independent variables was also checked and no significant violations occurred.

Table 2: Determinants of removing water hyacinth using manual labour

Variables	B	S.E.	Wald	Sig.	Eexp(B)
Sex (1)	-0.369	0.418	0.780	0.377	0.691
Age (years)	-0.035	0.024	2.196	0.138	0.965
Marital status (1)	0.207	0.764	0.073	0.787	1.230
Education level (1)	0.317	0.411	0.595	0.441	1.373
Family size (N^0 of members)	0.163	0.195	0.701	0.402	1.177
Type of terrain (1)	1.138	0.412	7.619	0.006	3.119
Water depth (1)	0.792	0.437	3.283	0.070	2.208
Presence of insects (1)	0.330	0.389	0.719	0.396	1.391
Household income (ETB)	0.000	0.000	1.078	0.299	1.000
Food availability (1)	1.414	0.420	11.353	0.001	4.114
Sharing farming time (1)	-0.997	0.453	4.843	0.028	0.369
Government support (1)	0.822	0.476	2.983	0.084	2.275
Availability of focus (1)	0.865	0.436	3.943	0.047	2.376
Employment (1)	1.151	0.544	4.475	0.034	3.161
Constant	-1.604	1.135	1.997	0.158	0.201

As shown in the regression coefficient (Table 2), people inhabiting levelled wetland terrains have positive relation with households' manually controlling practices of the water hyacinth expansion. Meaning, people in the relatively levelled wetland relief areas are more likely to participate in removing water hyacinth by the odds ratio of 3.119 as compared to those settled nearer to rugged wetland areas. This relation was also statically significant at $P < 0.01$. Rugged wetland terrains (cliffs, ridges and silt mounds) often cause injury on people during the harvesting times, and hence, discourage participation in the campaigns. Similarly, deeper waters hinder people to participate in water hyacinth removal campaigns. The result indicated that people living in shallower water environments significantly involved (significant at P=0.070) in the weed removal campaigns by more than 2.208 times than those found in the deeper water areas.

Sufficient food availability at home has positive relation with households' participation in the water hyacinth harvesting campaigns. Households having food at home participated in the weed removal campaigns with the odds ratio of 4.114 as compared to those faced scarcity of food at home. The relation was significant at $P < 0.01$ (Table 2).

Most of the people involved in harvesting water hyacinth from the Lake Tana wetlands were farmers living in the surrounding villages. Taking this in mind, it was assumed that households' participation in the weed removal campaigns would compete with their farming time, and hence, expected to reduce their participation in the weed removal campaigns. As expected, the regression output (Table 2) showed a significant and negative effect of the time variable. Time is therefore discovered significantly decreasing households' participation in the water hyacinth harvesting campaigns by a factor of 0.369 (significant at P=0.028).

Access to government support and availability of focus to the danger of the water hyacinth invasion were also found significantly increasing household participation in the labour campaign at P=0.084 & P=0.047 levels, respectively (Table 2). Government support with financial, technical and material incentives to the people involved in harvesting the invasive weed can develop interest among the farmers living in the adjacent villages and it may also attract distant farmers to join the eradication venture.

As to the binary logistic regression release statistics (Table 2), households with employed heads were able to participate in the weed harvesting practices by more than 3.161 times as compared to households led by non-employed heads (significant at P=0.034;). Government employees can get permissions from their respective offices when they plan to participate in the manual removal of water hyacinth. This can initiate them to repeatedly participate in the weed removal campaigns compared to those people who are not employed by government. The non-government employed people often fear losing their income when they go to the water hyacinth harvesting campaigns. This can hinder their participation in the campaigns.

CONCLUSION

The main objective of this study was to evaluate the determinants of manual control of water hyacinth expansion over the Lake Tana wetlands, Ethiopia. A total of 222 households, three focus groups and nine key informants were studied from April-September 2018 for data retrieval. The study revealed that the total water hyacinth cover in the Lake Tana Basin increased from ≤10, 000 ha in 2011 to >50, 000 ha in 2017. Thousands of people were mobilized to manually remove the weed from the Lake wetlands from 2013-2017. The physical removal of the weed was; however, focused on and limited to the levelled terrains and shallow water areas. Type of wetland terrain, water depth, food availability, farming time government support and employment were found significantly influencing the manual control practices of the invasive water hyacinth expansion.

The study recommended that government support and focus be increased to motivate people involvement in the manual removal of the invasive weed. Supporting food sufficiency of the people living in the area initiates them to devote more time in removing the weed. Suitable weed harvesting schedules have to be launched to encourage participation of government employees and to attract people who decline to participate when the weed removal campaigns share their farming times.

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