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ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF ENVIRONMENT AND SUSTAINABLE
DEVELOPMENT

CHALLENGES OF MANAGING THE IMPACT OF INVASIVE PLANTS ON THE
ENVIRONMENT: THE CASE OF WATER HYACINTH ON LAKE TANA,
(ACHERA AND ADISGE KEBELES), CENTRAL GONDAR ZONE, ETHIOPIA

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ADDIS ABABA, ETHIOPIA

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DECLARATION

I declare that, this thesis is my original work and has not been presented for a degree in any university and all the sources of materials used for the thesis are duly acknowledged.

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This thesis has been submitted for the examination with my approval as an Advisor:

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Table of Contents

	<i>Page</i>
<i>Acknowledgment</i>	V
<i>Table of Contents</i>	vi
<i>List of Table</i>	viii
<i>List of Figures</i>	ix
<i>List of Accronym</i>	x
<i>List of Appendices</i>	xi
<i>Abstract</i>	xii
Chapter I: Introduction	1
1.1 Background	1
1.2 Statement of the Problem.....	2
1.3 Research Questions	3
1.4 Objective of the Study.....	4
1.4.1 General Objective	4
1.4.2 Specific Objectives	4
1.5 Significance of the Study	4
1.6 Scope of the Study.....	5
1.7 Limitation of the Study	5
1.8 Definition of Terms.....	5
Chapter II: Review of Related Literature	6
2.1 Invasive species.....	6
2.1.1 Invasive Species Management Framework	6

2.2 Origin and Distribution of Water Hyacinth.....	8
2.3 Major Impacts of Water hyacinth.....	10
2.4 Managing water hyacinth problems	13
2.4.1 Major controlling methods	13
2.4.2. Policies and practices of Water hyacinth Management in Ethiopia.....	16
2.5 Major Challenges of Managing Water Hyacinth problems.....	18
2.6. Conceptual Framework.....	19
Chapter III: Research Methodology	21
3.1 Description of the StudyArea.....	21
3.2 Research Design.....	23
3.3 Target Population, Sample Size and Sampling Procedures	24
3.4 Data Gathering Instruments	25
3.4.1 Validity of the instruments	26
3.5 Data Analysis and presentation.....	26
Chapter IV: Challenges of Managing the Impact of Water hyacinth on Lake Tana.....	27
4.1. Socio-economic and demographic characteristics of respondents.....	27
4.2. The state of water hyacinth infestation.....	30
4.3. The major socio-economic and environmental impacts of Water hyacinth.....	35
4.4. The current management practices of water hyacinth in the area.....	40
4.5. The major challenges of managing water hyacinth in the area.....	44
Chapter V: Conclusion and Recommendations.....	50
5.1. Conclusion.....	50
5.2. Recommendations.....	51
Reference	54
Appendices	64

List of Table

Table 1: Sex and age composition of Respondents.....	27
Table 2: Educational Status of Respondents.....	28
Table 3: Respondents' Occupation.....	29
Table 4: Household size.....	29
Table 5: The first observation of water hyacinth in the area	31
Table 6: Respondents' perception on where water hyacinth comes from	31
Table 7: Respondents' occupation & perception on origin of water hyacinth.....	32
Table 8: Respondents' occupation & perception on origin of water hyacinth (Chi-square).....	33
Table 9: Responses on the category of water hyacinth expansion	34
Table 10: Perception between farmers and non-farmers to water hyacinth expansion.....	34
Table 11: Perception between farmers and non-farmers to water hyacinth expansion (t-test)..	34
Table 12: The economic impacts of water hyacinth.....	35
Table 13: Respondents occupation & perception on challenges of managing water hyacinth (Cross-tabulation).....	46
Table 14: Respondents' occupation and perception on the challenges of managing water Hyacinth (Chi-square test)	46

List of Figures

Figure 1: Management strategies to curtail invasive plants at different stages7

Figure 2: Global distribution of water hyacinth.....9

Figure 3: Conceptual Framework of the study.....20

Figure 3: Location of the study Area.....23

List of photos

Photo 1: Water hyacinth invaded area in Achera kebele37

List of Acronyms

BoFED	Bureau of Finance and Economy Development
CABI	Centre for Agriculture and Biosciences International
CSA	Central Statistical Agency
EBI	Ethiopian Biodiversity Institute
EFWPPDA	Environment, Forest and Wildlife Protection & Development Authority
EPA	Environmental Protection Authority
EEA	Ethiopian Economics Association
FAO	Food and Agricultural Organization
FGD	Focus Group Discussion
FWS	Fish & Wildlife Service
IAS	Invasive Alien Species
IDRC	International Development Research Centre
IUCN	International Union for Conservation of Nature
KII	Key Informant Interview
MoWR	Ministry of Water Resources
MSE	Micro and Small Enterprises
NECIS	National Environmental Coalition on Invasive Species
NISC	National Invasive Species Council
UNCCD	United Nations Convention to Combat Desertification

List of Appendices

Appendix A: Respondents' questionnaires

Appendix B: Key Informant Interview Questions

Appendix C: Focus Group Discussion Questions

Appendix D: Consent form for FGD and KII Participants

Abstract

Water hyacinth is one of the world's most invasive aquatic plants causing significant ecological and socio-economic impacts. Most of the problems are associated with its rapid growth rate, its ability to compete with other aquatic plants, and difficulties to manage its spread. Water hyacinth infestation on Lake Tana has been manifested on a large scale, and has created serious problems mainly on the environment and socio-economic activities. The study focused on the challenges of managing the impacts of water hyacinth on Lake Tana, Central Gondar Zone. A total of 226 households were drawn as representative sample using simple random sampling. The data gathering instruments used were questionnaire, key informant interview and focused group discussions. Data were described using frequency counts, percentages, Chi-square and Independent t-test. The results shown that water hyacinth expanded more and adversely affected the local environment. The major water hyacinth controlling practices were dependent on hand removal by local community. The result also revealed that low concern of the government, lack of appropriate technology to apply, and declining participation of local communities on manual removal of the weed as the major challenges of managing water hyacinth in the area. Besides, there is no significant perception difference between farmers and non-farmers on the expansion of water hyacinth ($p=.960$), and there is no statistically significant relationship between the participants' occupation and perception on the challenges of managing water hyacinth ($p=0.323$). Recommendations, government has to support and strengthen efforts undertaken currently, appropriate policy and strategies need to be formulated and strong institutional set up must be established, application of appropriate technology and integrated control methods have to be employed to effectively manage the problem.

Keywords: *Challenges, Impact, Management practice, Water hyacinth,*

Chapter I

Introduction

1.1 Background

Invasive species are species whose introduction and infestation threatens ecosystems and other species with socio-cultural, economic and/or environmental damage, including harms to human health (Rai, 2015). Primarily, aquatic invasive species affect socio-economic and ecological systems by invading freshwater ecosystems, and influencing their functionality and productivity as well as disrupting hydrological processes (Thamaga & Dube, 2018). Water hyacinth (*Eichhornia crassipes*) is one of the world's worst aquatic weeds. It is a free-floating and highly invasive weed that rapidly forms dense and impenetrable floating mats on freshwater systems (Osmond & Petroeschevsky, 2013). It has beautiful, large, pale-blue flowers, with purple and yellow spots on the petals and shiny, round green leaves (IDRC, 2000). Originally from the Amazon Basin in tropical South America, its entry into Africa, Asia, India, Australia, Central America North America and New Zealand largely facilitated by human activities. Now, it is found across the tropical and subtropical regions Dagno et al., (as cited in Mujere, 2015).

Most of the problems associated with water hyacinth are due to its rapid growth rate, its ability to successfully compete with other aquatic plants, and its ease of propagation. These characteristics give rise to enormous amounts of biomass that cover the water surface of a great variety of habitats often interfering with the use and management of water resources. Some of the principal problems are its interference with navigation, water flow, the recreational use and it causes damage to hydroelectric systems. It also acts as an agent for the spread of serious diseases in tropical countries (Télléz et al., 2008).

Mainly Africa has been affected by the introduction and spread of water hyacinth, facilitated in part due to a lack of naturally occurring enemies (UNEP, 2013). For instance, the weed caused a widespread crisis in South Africa in the 1910s, Madagascar in the 1920s, Tanzania, Uganda and Kenya in the 1930s through the 1970s. In the 1980s and 1990s, water hyacinth bloomed heavily on Lake Victoria, the Nile, the Congo and almost all watercourses of Africa (Kitunda, 2005).

The economic impacts of the weed in Africa may be reached as much as US\$100 million annually (UNEP, 2006).

The invasion of water hyacinth in Ethiopia has been observed on a large scale in many water bodies of the country and has created serious problems on water resources (Firehun, 2017). Water hyacinth has been infesting thousands of acreage of the edge and surface of Lake Tana, threatening the water level and livelihoods of communities around the lake. Lake Tana, the largest freshwater body in Ethiopia, is also a source of the Blue Nile River and provides a fishing potential of 50,000 metric tons per year. However, the Lake has been severely infested by water hyacinth, and posing a significant threat to livelihoods, biodiversity and tourism (FAO, 2017).

The explosive nature of water hyacinth infestation and its related problems have called for careful and organized efforts to control its expansion (Mahamadi, 2011). So far, different efforts such as physical control and other methods have been employed in Lake Tana by different actors to manage infestations but none of them have been able to completely control the weed.

1.2 Statement of the Problem

Water hyacinth has become the most terrible aquatic weed in the world since its widespread growth destroys native species and its high rates of transpiration causes four times the loss of water from normal water surface evaporation. It has also caused enormous negative effects on the environment, health and well-being of many people who look for their livelihood from the infested waters and the economy in general (Mujere, 2015).

In Ethiopia, water hyacinth has been recognized as the most damaging aquatic weed in the country since 1965 although its existence was officially stated in 1956 in Koka Lake and Awash River (Asmare, 2017). Since then the weed invasion has been manifested on a large scale in many water bodies of the country which has posed serious social, economic and environmental problems in the areas (Firehun, 2017). In Lake Tana, the presence of the weed was recognized in 2011(Asmare, 2017). In the Lake, the estimated water hyacinth coverage was nearly 20,000 hectares in 2012, and in just two years the estimated coverage of the weed reached to 40,000

hectares. Besides, more than 30% of the lake shore (128 km distance) is now invaded by water hyacinth (Wassie, 2014).

Taking the rapid infestation of water hyacinth, efforts were made in the area. According to Maheder (2017) farmers and the fishermen have been participated in the labor intensive weed removal work in Lake Tana- over the last few years, however the weed continues to come back and spread rapidly. Besides, a survey result confirmed that there is re-outbreak of water hyacinth infestation after the physical removal measure was taken (Wassie et al, 2014). These efforts were entirely ineffective in terms of controlling the spread of water hyacinth (Yihun & Wondwossen, 2017). These shows that managing the rapid infestation of water hyacinth in Lake Tana becomes challenging even though efforts have been made by different parties (Asmare, 2017). The environmental, social and economic consequence in the area would be hazardous if the problem is not sustainably solved. This study, therefore, attempts to examine why managing the infestation of Water Hyacinth in Lake Tana becomes challenging, and it proposes appropriate strategies for effective control of the problem.

1.3 Research Questions

Therefore, to guide the research process the following basic questions were designed:

- What is the status of water hyacinth infestation in the area?
- What are the current practices of managing water hyacinth in the area?
- What are the major challenges of managing water hyacinth in the area?
- What are the major impacts of Water hyacinth in the area?

In addition to the basic research questions indicted above, the following hypotheses were designed to further guide the research:

- There is no significant perception difference between farmers and non-farmers on the expansion of water hyacinth.
- There is no significant relationship between occupation and perception on the origin of water hyacinth.
- There is no significant relationship between occupation and perception on the challenges of water hyacinth.

1.4 Objective of the Study

1.4.1 General Objective

The main objective of the study is to investigate the challenges of managing the impact of Water hyacinth in the area.

1.4.2 Specific Objectives

The specific objectives include:

- To assess the status of Water hyacinth infestation in the study area.
- To examine the current practice of managing water hyacinth in the study area.
- To identify major challenges to control water hyacinth in the study area.
- To identify the major impacts of Water hyacinth in the study area.

1.5 Significance of the Study

This study is significant since it examines the magnitude of the problem caused by water hyacinth in Lake Tana, it identifies the current practices and assesses why the effort to control the spread not successful, which gave rise the question on the challenges of managing the weed.

It is expected that this study will be useful to the community as it will help them understand what the status of Water Hyacinth infestation on the study area and what approach should be used to manage the problem. Policy Makers and planners may use the findings of this study in their policy formulation regarding the application of water hyacinth management options. This study seeks to add information on the major challenges of managing the problem. It will also help academicians and future researchers to identify priority areas to carry out more research on options to control the problem effectively.

1.6 Scope of the Study

The study focused on the challenges of managing Water Hyacinth on two kebeles of Dembia Woreda, North Gondar Zone part of Lake Tana. This is because, Yihun & Wondwossen (2017), stated that based on local sources, water hyacinth was first observed on Lake Tana at Achera kebele of Dembia woreda in 2011. Besides, Solomon (2017b) indicated that among the 20 kebeles that are infested by water hyacinths, just four of them, Tana Woina, Achera, Seramba and Tezamba, accounted for 55% of the total weed coverage around the lake. On the contrary, in these areas efforts to control the weed invasion are fragmented and inconsistent. Thus, the study is restricted to Achera and Adisge kebeles since both areas are highly infested by water hyacinth.

1.7 Limitation of the Study

In conducting this study, the researcher faced the following major problems. The first problem was that the study area was remote and inaccessible for transportation made the travel tiresome.

1.8 Definition of Terms

Intermediate: occurring or situated between two points, extremes, places, etc; in between (Collins English Dictionary, 2014).

Invasive species: Foreign plants and animals that cause harm to the native ecosystem (Mabuye, 2010).

Minor: smaller in amount, extent, or size; lesser in seriousness or danger, one that is lesser in comparison with others of the same class (American Heritage Dictionary, 2016).

Severe: Serious in appearance or stern; critical or dangerous in manner (Collins English Dictionary, 2014).

Water hyacinth Proliferation: Rapid growth and spread of water hyacinth covering a large area of water body (Mabuye, 2010).

Chapter II

Review of Related Literature

2.1 Invasive species

Invasive species are widely considered as one of the most destructive environmental factors of our time, dramatically altering native habitats. Once an invasive species has established itself in a new environment, removing it through control measures is often difficult or impossible without causing further environmental damage (Seiler, 2017). It is estimated that the cost of managing invasive Alien Species globally accounts for US\$1.4 trillion annually or 5% of annual global Gross Domestic Product (GDP). Put in context this is double the annual GDP for the African continent (Witt, 2015).

Several strategies have been developed by different researchers to control the damage caused by invasive species and prevent future invasions. Among others, Priyanka et al, (2013), indicated Invasive Species Management Framework which shows the overall process of management of invasive species and prevention of future invasions.

2.1.1 Invasive Species Management Framework (ISMF)

The Invasive Species Management Framework is a systematic process intended for use by governments, private companies and individuals to identify the steps that need to be taken to minimize the damage on socioeconomic and ecological environment, and help efficient and effective management of invasive species. There are five elemental strategies which forms the baseline for any management framework. These include - prevention, early detection & rapid response, control & manage, legislation, and education & outreach which are directly or indirectly linked to curb invasive species at varied stages of invasion process (Priyanka, et al., 2013).

2.1.1.1 Prevention

Preventing the introduction or spread of invasive species is the first choice of defense against invasions (NISC, 2003). Prevention is the most cost-effective way of protecting aquatic

resources. However, some species inevitably escape detection and become established. But once established, aquatic species are difficult and often impossible to eradicate (FWS, 2016).

2.1.1.2 Early Detection and Response

When invasive species bypass prevention measures and enter, it is necessary to detect, identify and respond to them before - or immediately after - they become established i.e. when a species voyaging through introduction to colonization phase of invasion process (Fig.1). A Site-specific and general monitoring around critical points of entry, protected areas, urban and agricultural ecosystems is important (Priyanka, et al., 2013).

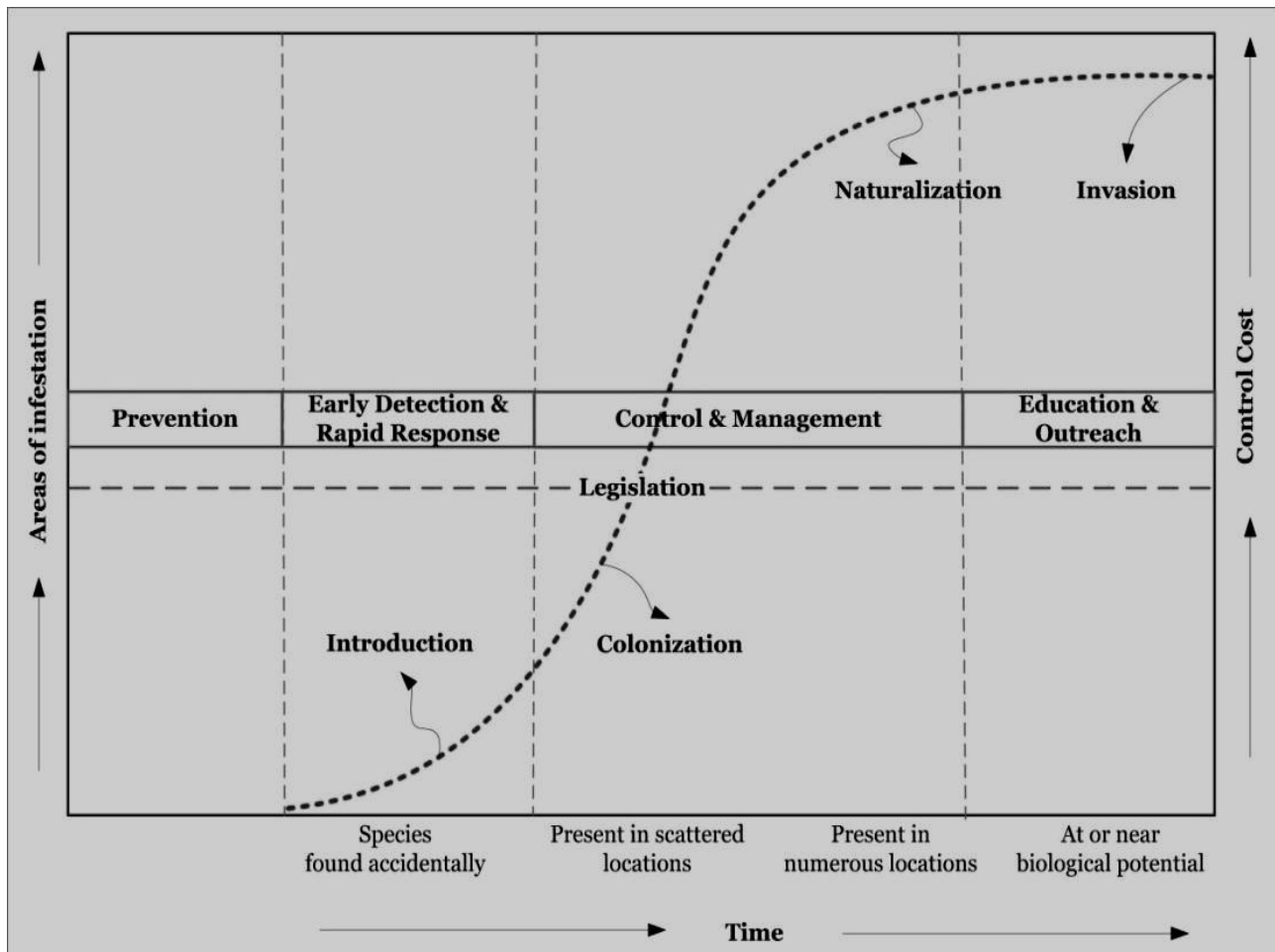


Fig.1: Management strategies to curtail invasive plants at different stages (Priyanka, et al., 2013)

2.1.1.3 Control and Manage

Controlling invasive species usually means containing an existing infestation through perpetual management actions, but may include reducing invasive populations, and sometimes, eradicating them. Concerned actors work closely with the public and private sector to develop and implement ways to control or eradicate invasive species (FWS, 2016).

2.1.1.4 Legislation

Legislation is one of the elemental strategies that aimed at preparation of legal and regulatory roles including responsibilities through the establishment of organized body and strategic plan that incorporates all relevant regulation and major stakeholders (Priyanka, et al., 2013). Smith et al. (2013) argue that a strong strategic legislative framework is essential for addressing the complex challenges of invasive alien species.

2.1.1.5 Education and Outreach

Education and outreach to the targeted audience is the most effective method of managing invasive species (Hare, 2016). This method aims to minimize the overall adverse impacts of invasive species throughout their potential range rather than attempting to manage the invasive species population itself i.e. a species at invasive stage of invasion process. Here, asset-based approaches are commonly adopted to manage it (Priyanka, et al., 2013).

2.2 Origin and Distribution of Water Hyacinth

Water hyacinth is an aquatic plant native to the Amazon basin, and is often a highly problematic invasive species outside its native range (Shubhangi & Sagar, 2017). This species was discovered in 1823 by the German naturalist C. von Martius who was studying the flora of Brazil (Télez et al., 2008). The native range of the weed in South America includes Argentina, Brazil, Paraguay, Uruguay, Bolivia, Ecuador, Colombia, Chile, Guyana, Surinam and Venezuela (Jones, 2009). In its native range, it is mostly confined to slow-moving water areas such as coastal lowlands and the margins of lagoons (Osmond & Petroschevsky, 2013).

CABI (as cited in Firehun, 2017) indicated that starting from the end of nineteenth century water hyacinth weeds were taken from its origin to the rest of the world as an ornamental and botanical gardens plant. According to Mujere (2015), there are basically three ways in which the weed may be dispersed from one location to another: (1) water-borne dispersal which demands connection between water bodies; (2) birds and animals that feed in sites of water-hyacinth infestation transport seeds over large distances on their feet; and (3) people as an ornamental garden pond plant. This is how it was introduced into the Congo River, Egypt and Uganda.

Its infestation throughout the tropics and subtropics is reported from early 20th century. At present, water hyacinth is the most problematic aquatic weed of Central and North America, Africa, India, Asia, Australia and New Zealand (Sharma et al., 2016).

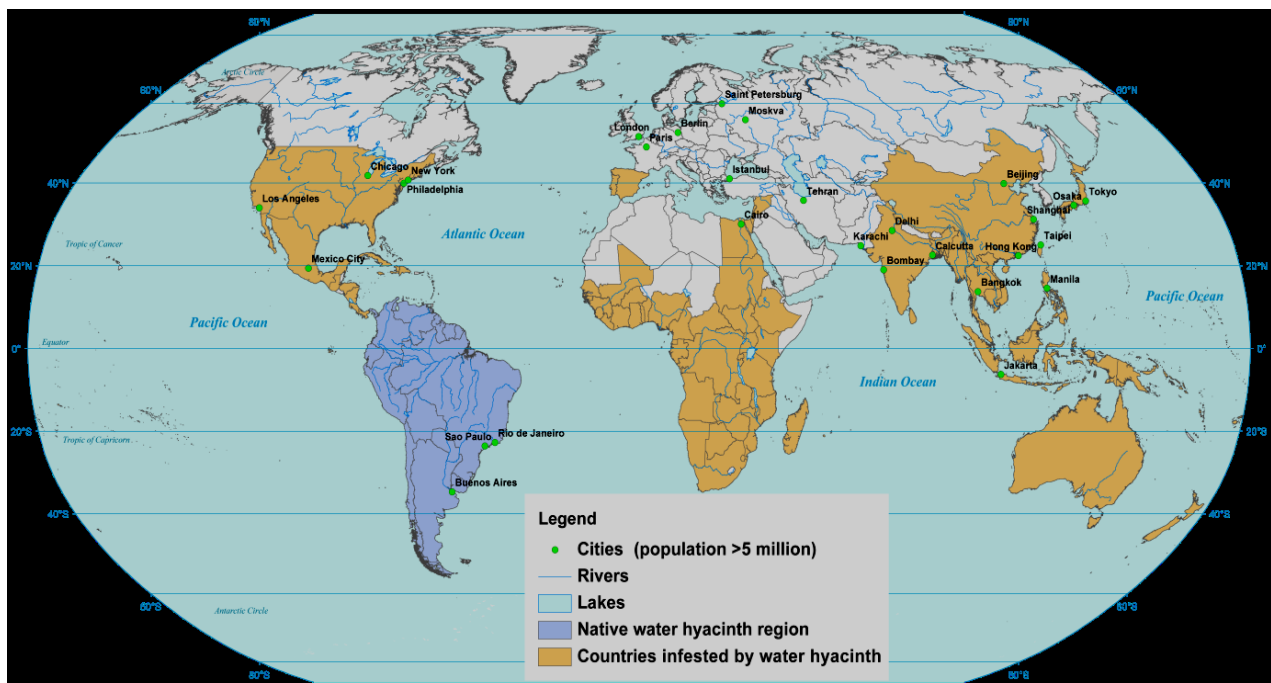


Fig. 2: Global distribution of water hyacinth (UNEP, 2013)

In Africa, the first introduction of water hyacinth was in Egypt in about 1880. The spread of the weed has been rapid during the last 10-15 years with exceedingly serious problems of growing in the equatorial zone (Mironga, 2014). Major infestations occur on Lake Victoria in East Africa, where more than 12,000 hectare of the lake was infested with water hyacinth, Lake Malawi and

the Zambezi River basin in southern Africa, and the Tano lagoon and River Niger, all in West Africa (Osmond & Petroeschevsky, 2013).

Stroud, Rezene, Taye et al. (as cited in Friehun, 2017) stated that in Ethiopia the introduction and rapid spread of water hyacinth in the Awash River Basin (Koka Lake, Koka Dam), Abbay River Basin (Lake Tana, Blue Nile), Baro-Akobo River Basin (Sobate, Baro, Gillo and Pibor rivers) and Rift Valley Basins System (Lake Ellen, Lake Abaya, Lake Elltoke), became hindrance on the utilization of the existing water resource.

Water hyacinth was officially recognized in 2011, as one of the top ten ecologically harmful and worst invasive weed type that has been invading Lake Tana. At present, the Lake is found in serious ecological problem that has been affecting its aquatic biodiversity, occupying the northern, northeastern and eastern shores of the Lake (Solomon, 2017b.).

2.3. Major Impacts of Water hyacinth

2.3.1 Adverse impacts of Water hyacinth

Water hyacinth has been identified as one of the 100 most aggressive invasive species and identified as one of the top ten worst weeds in the world (Patel, 2012). Most of the problems associated with the weed are due to its rapid growth rate, its ability to successfully compete with other native aquatic plants, and its ease of propagation. These characteristics give rise to huge amounts of biomass that cover the water surface of a great variety of habitats often interfering with the management of water resources and becoming a threat (Téllez et al., 2008).

This condition is causing environmental, economic and social problems and accumulated damages that can easily be valued in the order of billions of dollars. This has direct effects on communities that in one way or another depend on the environmental services or production from affected water bodies (Chapungu, et al., 2018).

Some of the major ecological and socio-economic problems that water hyacinth has brought on include the following:

- **Ecological Impacts**

Large water hyacinth mats usually prevent the natural transfer of oxygen from the air to the water surface, or reduce oxygen production by other aquatic plants and algae (UNEP, 2013). Besides, aquatic weeds affect native plants and animals by altering local ecosystems, and the reduced sunlight penetration will suppress the growth of some plants and cause some animals to move to new locations (World Bank, 2003).

According to Patel (2012) water hyacinth is challenging the ecological stability of freshwater bodies, in different parts of the world, by out-competing all other species growing in the vicinity, thus, posing a threat to aquatic biodiversity. In addition, Mujere (2015) indicated that water hyacinth negatively affecting the growth of native plants and microbes, preventing the growth and abundance of phytoplankton under large mats. As a result, many aquatic plants have difficulty in surviving. Rahman (2008) stated that this condition leads to a disproportion in the aquatic micro-ecosystem and often means that a range of fauna, like fishes that rely on a diversity of plant life for its existence will be destroyed.

- **Socioeconomic Impacts**

Water hyacinth often blocks waterways due to its rapid reproduction and propagation rate. As a result, the dense mats directly disrupt socioeconomic and subsistence activities (UNEP, 2013). For fishermen, the hyacinth mats have reduced their catch by covering the water grounds, increasing fishing costs because of the time and effort spent in clearing waterways, and causing loss of nets (Asmare, 2017). This aquatic weed also obstructs irrigation activities by preventing predicted water flow in channels, blocking irrigation pumps and destroying water dams (Center et al., 2002).

Besides, many large hydropower schemes are suffering from the effects of water hyacinth. For example, the Owen Falls hydropower scheme at Jinja on Lake Victoria, the Kariba dam which straddles the Zambia-Zimbabwe border on the Zambezi River, and Koka hydropower dam in Ethiopia suffer from the rapid reproduction rates of water hyacinth (Frieahun, 2017).

- **Impacts on Human Health**

Water hyacinth primarily offers a micro-habitat for a variety of disease vectors such as snails that are detrimental to human health. Diseases associated with the presence of aquatic weeds in tropical developing countries are among those that cause the major public health problems: malaria, schistosomiasis and lymphatic filariasis (Mujere, 2015). In addition, a study by Honlah et al., (2019) water hyacinth invasion caused major health problems in riparian community mainly associated with poor sanitation in the form of bushy environment and stagnant water.

2.3.2 Possible Benefits of Water hyacinth

While various literature that mention water hyacinth has been causing ecological and socioeconomic problems in different parts of the world, there are also some studies that indicate the useful applicability of the weed. They include:

- **Biogas Production**

Water hyacinth can be an ingredient for the production of biogas, an ideal clean energy source. The development of biogas can improve ecological and environmental conditions, such as reducing deforestation. It can also be used for cooking and generating electricity. Its residue contains regular nutrients, organic matter, trace elements, amino acids and vitamins, etc., which makes both quick and slow organic compound fertilizers (Su, et al., 2018).

- **Raw material for local industries**

Researches indicate that water hyacinth can be used as raw material for local industries. For instance, Tacio (as cited in Mbula, 2016) stated examples such as; Bangladesh, Philippines, India and Indonesia have been experimenting with paper production from the water hyacinth and successfully produced it.

- **Animal fodder and fertilizers**

According to Mbula (2016), studies have shown that water hyacinth has nutrients and potential uses as animal feed. Besides, the organic matter obtained from the weed can be used as fertilizer and provides essential nutrients to crop growth.

- **Other Uses**

There are also other uses of the weed, such as: decomposed water hyacinth can be used as green manure or as compost that improves poor quality soils (Ndimele et al., 2011). The weed can also quickly absorb some heavy metals in the water and can be used in controlling water pollution (IDRC, 2000).

2.4. Managing water hyacinth problems

Management is about coming up with solutions to problems that keep emerging from time to time in an organization's effort to achieve its objective. The process of solving this problem starts with identification of the problem followed by analysis and strategy development. Equally, establishing pertinent rules and regulations for the execution, control, communication, delegation and crisis management is noteworthy. However, these rules and regulations should not be seen as ends by themselves rather they are means to achieving the desired result (Ayoo, 2017).

The management of water hyacinth requires diligent planning and control efforts due to its long-lived seed bank, high vegetative growth rates and ability to produce large amounts of viable seed within 12 weeks of germination (Osmond & Petroeschovsky, 2013). If water hyacinth is not checked, it will choke out all water life, bring to a halt any economic activity on water bodies and drastically affect the environment and its contribution to development (Mujere, 2015).

2.4.1 Major controlling methods

Today, a large number of methods are being used and millions of dollars are being spent to control it. These weed management methods include: physical removal, chemical methods and release of biological control agents. Each of these methods has certain advantages and disadvantages and thus any of the methods alone is ineffective (Sharma et al., 2016).

- **Manual Control**

Manual removal of water hyacinth from small areas of water such as farm dams and drains is an effective form of controlling water hyacinth, but only when the rate of removal is faster than the rate of re-growth. On a larger scale, manual removal is less likely to achieve control of the weed (Ensbey, 2009). Nevertheless, manual removal is difficult because it is labor intensive and in some areas there are serious health risks associated with the work such as crocodiles, hippopotamus and bilharzia in Lake Victoria for example. Transportation of the harvested weed is also costly, because it has high water content (Mujere, 2015).

- **Mechanical Control**

Mechanical control operations involve machines, and have so far consisted solely of chopping and dumping of the chopped pieces of water hyacinth and other weeds into the lake (Mabuye, 2010). However, the overall application of this method require large amount of money. As Lwasa & Mwanje (2002) stated that a haybaler machine used in Sudan, apart from its high procurement and maintenance costs, lasts from 3.5 to 4 years. A mechanical harvester recently procured by URC from Britain at US \$250,000 never worked satisfactorily. Besides, as Solomon, (2017a) stated that in Lake Victoria an estimated 60,000 hectares is covered by the weed on the Kenya part of the Lake alone, and a weed harvesting machine can clear only 10 hectares a day. So it would take 6 000 days (more than 16 years) to remove the weed entirely.

- **Chemical Control**

This method involves the application of herbicides for controlling water hyacinth (Mujere, 2015). Herbicides can offer a cheap, effective and rapid method of water hyacinth control. However, they are powerful tools which require knowledge and understanding to be used safely and effectively. If misused, they can have side effects that may be harmful to aquatic organisms, wildlife in general and, ultimately man (Mbory, 2014). In the 1960s, various research articles reported on use of herbicides for the control of infestations of the weed. Since then various types of herbicides have come on the market showing different degrees of effectiveness and environmental consequences. (Télliez et al., 2008).

- **Biological Control**

The search for biological control agents began in the early 1960s and continues today (Julien, et al., 2001). Biological control agent is a control agent based upon a living organism or virus; it relies on the use of host specific natural enemies (insects, arachnids and pathogens) from the weed's region of origin, so that water hyacinth is attacked by arthropods in its native range (Mbory, 2014).

Biological control of water hyacinth is often the preferred control method even though its successfulness is slow commonly taking two to six years in tropical and subtropical countries (Julien et al. 1999). For instance, Labrada et al., (as cited in Mbula, 2016) in Australia, the method has been successful through regular release of the weevils *Neochetinaeichhorniae* and *N. bruchi*, and the moth *Sameodesalbiguttalis*, and has successfully reduced the population density of water hyacinth.

Biological control of water hyacinth is said to be environmentally compassionate as the control agents tend to be self-regulating. It is also inexpensive due to the fact that the control agents are known and only a small number of staff is required to run such programs (Mabuye, 2010).

Gopal (as cited in Téllez et al., 2008) stated that today there is a global agreement among scientists and managers that there is no totally effective method to eradicate water hyacinth indicating the best option is integrated management and control of the weed. Each of the methods that have been studied and used has their particular characteristics of time, effort, cost, environmental consequences, and efficacy so that the combination of various agents has been proposed to best control it.

2.4.2 Policies and practices related to Water hyacinth Management in Ethiopia

The Constitution of The Federal Democratic Republic of Ethiopia, (Proclamation No.1/1995) is the foundation for subsequent legislations in the environmental management as well as for mainstreaming environmental sustainability in the political, social and economic development sectors. It holds provisions, which recognize the importance of the environment protection and the need for its proper management (EPA, 2004).

An effective national invasive species response must include policies, strategies and actions intended to prevent introductions of additional non-native species, to detect and quickly respond to new invaders, and to control or manage already established invasive species (NECIS, 2013). In this section, relevant policies such as Environmental Protection Policy, Water Resource Management Policy and Biodiversity Conservation and Research Policy objectives are highlighted.

2.4.2.1. Policies Relevant to manage water hyacinth

- **Environmental Policy of Ethiopia**

The Environmental Policy of Ethiopia was issued in 1997 to provide a framework for overall guidance in the conservation and sustainable utilization of the country's environmental resources. The overall objective of the policy is to promote the sustainable social and economic development of the country through sustainable management and utilization of the resources of the country. Among the specific objectives the environmental policy seeks to achieve are ensuring the conservation, development and sustainable use of essential ecological processes and life support systems, incorporate full economic, social and environmental costs and benefits of natural resource development into the planning, implementation through comprehensive valuation of the environment and the services prevent the pollution of land, air and water in the most cost-effective way, and the empowerment and participation of the people in environmental management. Besides, different proclamations and strategies have been formulated (EPA, 1997).

- **Ethiopian Water Resources Management Policy**

The national Water Resource Management Policy was issued in 1999. The overall goal of the policy was to increase efforts to ensure efficient, equitable and optimum utilization of the available water resources of the country for improved socioeconomic development in a sustainable manner. Some of the policy objectives also focused on managing and combating not only drought but also other disasters in a careful management of water resources, and conserving, protecting and enhancing water resources and the overall aquatic environment on sustainable basis. The Policy further declares that water is a common property of all Ethiopians (MoWR, 1999). Besides, the policy provisions emphasizes the necessity of integrated water resources management approach and that all aspects of water resources management including the management of surface and groundwater resources, water quality and quantity issues should not be treated separately or in a fragmented manner rather it needs to be integrated with other aspects of natural resources management, which implies for inter-sectoral coordination at both the Federal and Regional levels (Solomon , 2016).

- **Biodiversity Conservation and Research Policy**

The mandate of the Institute of Biodiversity conservation and Research (now Ethiopian Biodiversity Institute) is to undertake conservation and promote development and sustainable utilization of the country's biological resources, namely: plants, animals and microbial genetic resources as well as associated community knowledge and the ecosystems. On the basis of national legislation, the institute has the responsibility and duty to implement international conventions, agreements and obligations on biodiversity to which Ethiopia is a party (EBI, 2014). All the above relevant national policies with their specific proclamations, strategies and action plans can be taken as important provisions to guide the sustainable utilization and management of mainly biodiversity and water resources in a protected and safe environment.

2.4.2.2. Water hyacinth Management practices

The precise management measures adopted for any plant invasion will depend upon factors such as the terrain, the cost and availability of labor, the severity of the infestation and the presence of

other invasive species although the best form of management is taken as prevention (BioNET-EAFRINET, 2011).

Water hyacinth continues to spread in different areas of Ethiopia although efforts have been made to control the infestation of the weed. According to Frieahun (2017), methods to control and contain the weed in Ethiopia include manual as well as mechanical clearing and in some spots also chemical control. Use of herbicides, even though effective, is not popular in Ethiopia because of high costs and pollution problems.

According to Yihun & Wondwossen (2017), in Lake Tana fragmented efforts to control water hyacinth have been going on since 2012. These efforts were mainly focused on mobilizing affected farming communities to uproot and dispose the weed manually. Clearly, these efforts were utterly ineffective in terms of controlling the spread of water hyacinth. Solomon (2017a) stated that local authorities mobilized an estimated 162,000 people to remove the weed by hand. This happened only when the lake shores are accessible and when farmers have time

On the other hand, a study at Wonji-Shewa Sugar Factory by Firehun et.al, (2007), stated that even though the Factory has been practicing manual and mechanical control of the weed since its occurrence, it colonizes the irrigation and drainage water structures at an alarming rate. In general, different literature indicated that efforts are being made to mobilize local people for physical removal of the weed, the use of some common scientific methods specifically biological controlling methods with direct engagement of some higher educations in weed management. Moreover, some Environmental awareness efforts were also taken through local communications media to obtain support and participation in preventing the plague.

2.5 Major Challenges of Managing Water Hyacinth problems

Today there is a global agreement among scientists and managers that there is no totally effective method to eradicate Water hyacinth indicating the best option is integrated management and control of the weed. Each of the methods that have been studied and used have their particular characteristics of time, effort, cost, environmental consequences, and efficacy so that the combination of various agents has been proposed to best control the weed (Télléz et al., 2008).

Public awareness in all aspects of the weed is of paramount importance, including conducting further research on various methods and combinations of all methods to create optimum weed control and economic and health benefit (Mujere. 2015).

People have been trying to remove the plant from many water ways, spending billions of dollars in doing so. In many cases this removal is coming to impossible (Jafari, 2010). The control of water hyacinth became expensive; in China for example the costs are annually estimated to be 1billion dollars per year (Valk, 2015). Water hyacinth weed is also heavy to remove manually since 90 % of the plant's content is water, which can correlate to up to 500 ton in weight per hectare. It is also known that the size of an area can double in just two weeks which also makes the job to remove the plants harder (Rahman, 2008).

Public awareness creation and mobilization efforts by environmental activists as well as concerned authorities on the scale of the problem are low and inconsistent. Besides, (Sotolu, 2013) stated that several researches on the utilization of water hyacinth have been carried and results seem not to be readily available for its effective adoption and replication.

Synergies are lacking across management, policies and decision making as there are insufficient networking, coordination and collaboration across organizations and departments to manage invasion. Thus, sustainable management of invasive species is challenging but inevitable given the increasing range of alteration caused by invasion which has little prospect of irreversibility (Priyanka, et al., 2013).

2.6. Conceptual Framework

The conceptual framework offers a logical structure of connected concepts that help provide a picture or visual display of how ideas in a study relate to one another within the theoretical framework (Grant & Osanloo, 2014). The following conceptual framework indicates the variables of the study and their relationship.

With regard to challenges of managing water hyacinth in the area, it is conceptualized that the state of water hyacinth infestation in the area is expanding and the management practice applied did not contribute a lot to keep the infestation under control. This leads to more adverse impacts

in the environment and socio economic condition of people in the area. Therefore, water hyacinth in the area must be effectively managed and sustainable use of the lake should be assured to lead towards sustainable development.

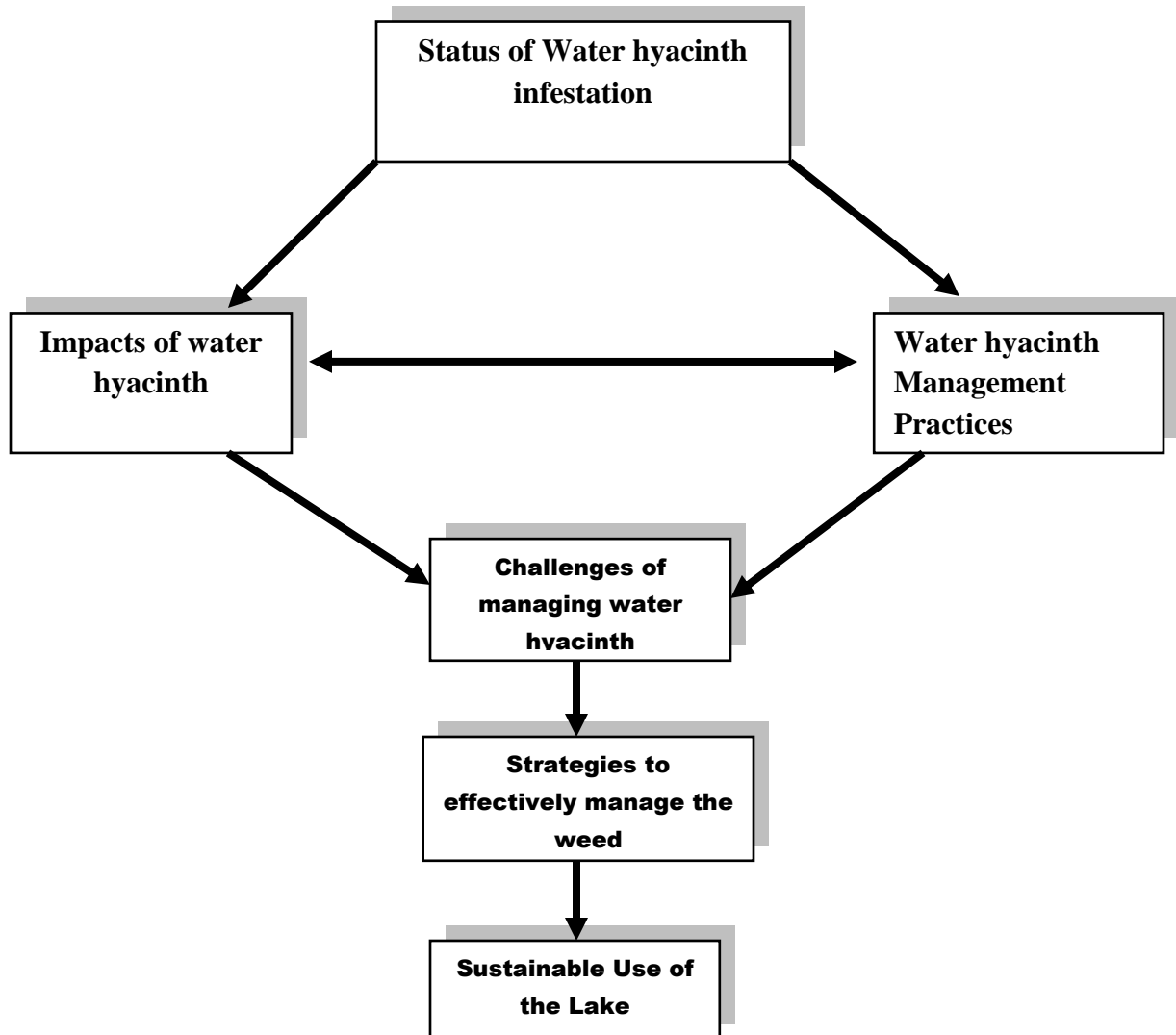


Fig. 3: Conceptual Framework of the study

Chapter III

Research Methodology

3.1 Description of the Study Area

Lake Tana is geographically located in the north-western part of Ethiopia, between latitude $10^{\circ}58' - 12^{\circ}47'N$ and longitude $36^{\circ}45' - 38^{\circ}14'E$. It has a surface area of about 3,200 Sq km, a mean depth of 8 meters and maximum depth of 14 meters with fluctuations due to increasing siltation levels. It is also the largest freshwater body in the country, contributing about 50% of the water resource of the nation (Wassie et al, 2014). The climate of the Lake is characterized by four seasons: the main-rainy season with heavy rains happens during July–September, a post-rainy season comes during October–November, a dry season during December–April and a pre-rainy season during May–June (Eshete et al., 2017). The lake is bounded by low plains in the north (Dembia), east (Fogera) and south-west (Kunzila) that mostly experience flooding in the rainy season (Tewabe, 2015). On the south, the lake is bounded by Bahir Dar town, which is the capital of Amhara region (Vijverberg, Sibbing & Dejen, 2009).

The study was undertaken in Achera and Adisge kebeles of Dembia woreda, bordering parts of Lake Tana. The woreda is located in Central Gondar Zone of the Amhara Regional State, northwest Ethiopia. It is bounded with Gondar town and Lay Armachiho woreda in the north, Gondar Zuria woreda in the east, Chilga and Alefa-Takusa weredas in the west and part of Lake Tana in the south. The woreda capital, Koladiba, is located 750 km North of Addis Ababa which is branched to west from Addis-Gondar highway at Azezo about 35 km away from Gondar city (Teshome, 2016). Geographically, the woreda is located between $12^{\circ} 11' 33''$ and $12^{\circ} 37' 16''$ N latitude and $37^{\circ} 03' 21''$ and $37^{\circ} 29' 07''$ E Longitude.

According to Dembia Woreda Agriculture and Rural Development Office (2017) annual report, as cited in Dessie et al., 2018, the woreda has 45 kebeles of which 40 are rural and the remaining 5 are urban centers. Besides, Dembia woreda has a total population of 311,398 of which 157,876 are males and 153,522 are females. From the total population 276,886 (88.9%) constitute rural

and 34,512 urban population (CSA, 2013). In terms of climate, the woreda is characterized by the mean annual rainfall of about 1200 mm which falls mostly in the months between May and September, and the annual mean minimum and maximum temperatures of 17°C and 28 °C, respectively (Kahasy cited in Muluneh, 2016).

Topographically the study area lies in the proximity of Lake Tana with altitude ranging between 1563 – 2469 meters above sea level. The largest area is found in southern and south central part of the study area with an altitude range of 1760-1859 meters. Areas with the altitude ranges from 1969 – 2469 comprise the northern and northwestern portions of the catchment while areas with altitude between 1860 – 1968 comprise the narrower part and extend from east to west and to the southern parts of the area. Plains dominate much of the area, i.e., 87.8%, while the mountain slopes and valley bottoms account for 12.2% (Dembia Woreda Agriculture & Rural Development Office, 2017 as cited in Dessie et al., 2018).

Out of the total area of the woreda, 32.97 % is being used for annual crop production, 12.75 % for grazing, 5.65 % for forest development, bush and shrubs, 15.95 % is degraded (unproductive) land, 4.37 % for residential purpose and 28.31% of the area constituted of water bodies. In terms of economic activities, the dominant economic sectors in Dembia woreda are crop production and livestock keeping. The average landholding size of the households is 0.87 hectare. The area is endowed with natural resources such as perennial river, spring, pond and well water resources, which are good for small-scale irrigation and other water development schemes (Teshome, 2016).

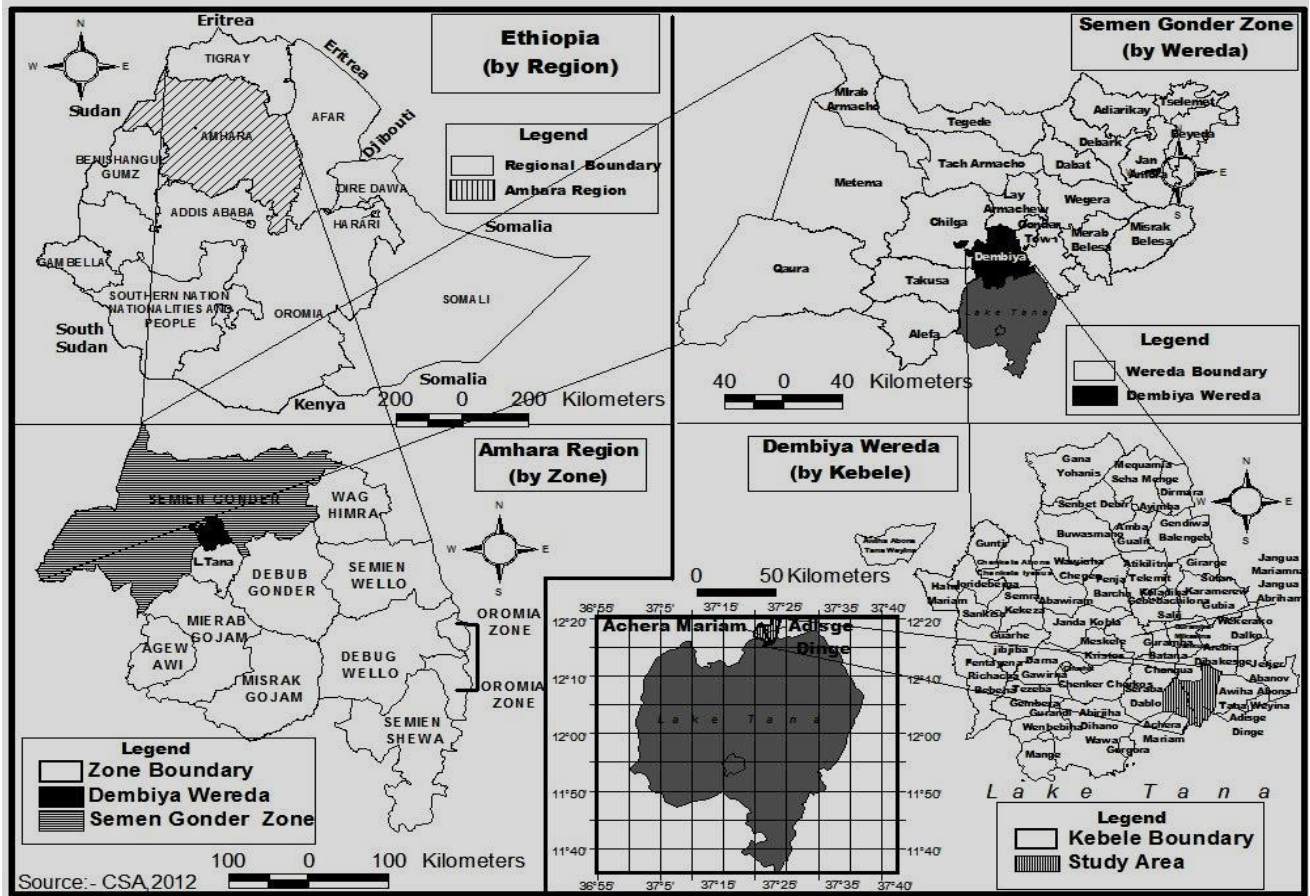


Fig. 4: Location of the study Area

3.2 Research Design

Research design is the conceptual structure within which research is conducted; it comprises the blueprint for the collection, measurement and analysis of the available data (Kothari, 2004). The study aimed at describing the challenges of managing the impact of water hyacinth in Lake Tana. In order to answer research questions, the study employed a survey method that was applied. A survey is an attempt to collect data from members of a population in order to determine the characteristics and perceptions of people who take part in the study (Mugenda & Mugenda, 1999). Therefore, this research design guided the study in search of the major challenges of managing the impact of Water hyacinth in the target areas.

3.3 Target Population, Sample Size and Sampling Procedures

Target population is a population to which a researcher wants to generalize the results of the study (Mugenda & Mugenda, 1999). The target population for this study encompassed all the households of Achera and Adisge kebeles of Dembia woreda, Central Gondar Zone. The selection of the study area was purposive because of the fact that water hyacinth infestation in Dembia woreda is higher than the remaining woredas and highly affecting agricultural activities (Endeshaw, 2018). Moreover, both kebeles were selected by the researcher due to their proximity to the Lake and especially Achera kebele was the first area where water hyacinth was observed in 2011/2012 (Yihun & Wondwossen, 2017). Therefore, the area was used as a target population from which a representative sample were selected for the study.

Based on the information obtained from Dembia Woreda Administration Communication Office (2018) the total number of households in the study area are 566 (Achera kebele has 173 households and Adisge kebele has 393 households). Hence, based on Krejcie & Morgan *table for determining sample size from a given population* (1970), 226 households (of this 69% from Adisge and 31% from Achera kebele) were drawn as representative sample. From the given questionnaires 177 respondents completed and returned them, and this was used for final analysis. The next step involved was the selection of the required household from the list, which was done through systematic sampling method. Kothari, (2004) indicated that this method is the most practical way of sampling to select every i^{th} item on a list. An element of randomness is established into this kind of sampling by using random numbers to pick up the unit with which to start. Thus, in systematic sampling only the first unit is selected randomly and the remaining units of the sample are selected at fixed intervals.

Furthermore, the researcher purposively selected farmers, fisher men and persons engaged in water transportation services from both kebeles for Focus Group Discussion with understanding that they have direct relationships with the issue under study. Therefore, the discussants were grouped in to three (11 farmers, 10 fisher men and 8 individuals working on water transportation) and each separately participated in the discussions. Therefore, a total of 29 focus group discussants were participated. Finally, the key informants were interviewed to supplement

and provide in depth explanation on the information obtained from the individual interviews and the focus group discussions (FGDs). They were purposively selected from Amhara Regional State Environment, Forest and Wildlife Protection and Development Authority and include (at region, Zone and Woreda level). The key informants included were 2 department heads (1 at region level using telephone interview and 1 at Woreda) and 4 officers in the respective offices. Therefore, a total of 6 key informants were interviewed.

3.4 Data Gathering Instruments

Both primary and secondary data gathering instruments were used. Regarding primary data gathering, the researcher made communications with relevant heads of departments and experts at region, zone, woreda and kebele level who assisted in map out the area to identify the households and collect the data.

The next step was the actual field work that involved collecting primary data from study participants. Three instruments designed to collect the data were: Questionnaire, Focus Group Discussions and Key Informant Interview. Moreover, relevant documents were analyzed. The questionnaire that involved both closed and open-ended items was used to collect primary data from individual respondents. The questionnaire consisted of the first part sought the respondent's basic information, and the other part were issues related to the study objectives and research questions. The responses received were used to address the objectives of the study and answer the research questions. Regarding Focus Group Discussion (FGD), there were three focus group discussions (for farmers, fisher men and people working in water transportation) to gain a deeper understanding of the issues under investigation. In addition, Key Informant Interviews were arranged purposively for participants from relevant government office (Environment, Forest and Wildlife Protection and Development Authority) at region, zone and woreda level.

Secondary data was obtained from reviews of other research findings with experiences from similar or related researched studies regarding the infestation of water hyacinth, the adverse impacts and challenges to manage the weed. Besides, Government and Non-governmental organization reports, policy documents, papers, articles, journals, books, and other relevant documents were also reviewed.

3.4.1 Validity of the instruments

According to Saunders et al. (2007) validity is the extent to which data collection method accurately measures what they are intended to measure. Therefore, in time of constructing the items in the questionnaire, simple words that the respondents can easily understand were used. Moreover, efforts were made to ensure that the items are clear and precise without any ambiguity to properly address the objectives of the study. The instruments were given to researchers for expert judgment and finally given to thesis advisor.

3.5 Data Analysis and presentation

The data collected was analyzed through quantitative and qualitative data analyses techniques. The quantitative data, obtained from questionnaires, was coded into the SPSS program (Version-21) and then descriptive statistics such as frequency count, percentages, t-test and Chi-square test were used to analyze it. Qualitative data obtained from key informant interviews and Focus Group Discussion were transcribed, and together with the open-ended questions in the questionnaires, organized and then discussed under the main objective areas of the study. Results from data analyzed were presented using tables and narrative to provide a clear understanding.

Chapter IV

Challenges of Managing the Impact of Water hyacinth on Lake Tana

This chapter presents the demographic and socio-economic characteristics of the respondents. The analysis of respondents' perception towards the origin and rate of water hyacinth expansion, and challenges of managing water hyacinth were made, discussed and presented in the following sections of the study.

4.1. Socio-economic and demographic Characteristics of the Respondents

The socio-economic and demographic characteristics of the target population give the required information about the sample population involved in the study. The major characteristics were presented below.

4.1.1. Sex and Age composition

The sex composition of the respondents was one of the demographic attributes this research dealt with. As indicated in table 1 below, 57.1% respondents were male and the other 42.9% were female. From this we can understand that the participation of females were closer to males. This implies that the study collected nearly representative data from both sexes.

Table 1: Sex and age composition of respondents

Category	F	%
Male	101	57.1
Female	76	42.9
Total	177	100
18 – 29 years	78	44.1
30 – 59 years	92	51.9
60 years and above	7	4.0
Total	177	100

Source: Own survey 2019

With regard to age composition, 51.9% of the respondents were between the age of 30 – 59 years, 44.1% of the respondents were between the age of 18 – 29 years, and 4% of them were 60 years and above. This shows that people between the ages of 18 – 59 years were considered physically more active than other age groups. This also implies that this category of people can participate in weed control efforts and can give adequate information about the problem.

4.1.2. Educational Status

Educational status was another characteristic of sample respondents. Based on the data indicated in table 2 below, 28.3% of the respondents cannot read and write, 19.2% have primary education level while 52.5% of the respondents have secondary education level and above. This indicates that the majority of respondents in the study area can read and write. This implies that these groups of people are considered educationally better to understand about the problem, and contribute in the effort to manage the weed.

Table 2: Educational Status of Respondents

Educational Level	F	%
Illiterate	50	28.3
Primary education (1-8 grade)	34	19.2
Secondary education (9-12 grade)	73	41.2
Post-Secondary (Certificate/ Diploma /Degree)	20	11.3
Total	177	100

Source: Own survey 2019

4.1.3. Occupation of Respondents

It was also necessary to establish the respondents' occupation so that the effect of water hyacinth to the economic activities of the respondents could be determined. The results were presented in table 3.

Table 3: Occupation of Respondents

Occupation	F	%
Government employee	9	5.1
Farmer	101	57.1
Fisher men	26	14.7
Water transport service	16	9.0
Jobless	10	5.6
Others	15	8.5
Total	177	100

Source: Own survey 2019

The data from table 3 indicated that 80.8 % of the respondents were farmers, fishermen, and water transporters. Hence, large proportion of the population in the area have direct association with the Lake for their livelihood while 8.5% of the respondents, i.e. others (such as petty traders, daily laborers, carpenters, etc), 5.6% jobless, and 5.1% government employees. This implies that the majority of the population in the area has faced impacts of water hyacinth on their livelihood than other groups of people.

4.1.4. Household size

Determining household size of respondents was taken important to understand the effect of water hyacinth at household level in the area. The results were shown in table 4 below.

Table 4: Household size of Respondents

Household size	F	%
One	11	6.2
2 - 4 members	67	37.9
5 – 7 members	68	38.4
Above 7 members	31	17.5
Total	177	100

Source: Own survey 2019

Regarding the household size, 38.4% of the respondents have a household size between 5 to 7 members, 37.9% of the respondents have between 2 to 4 members, and 17.5% of the respondents have household size above 7 members, whereas 6.2% of the respondents have single members. This indicates that more than half of the respondents have household size of 5 and above. This implies that the livelihood of households with larger members will possibly be affected by the impact of water hyacinth as land holdings are mostly fixed.

4.2. The State of Water Hyacinth Infestation

4.2.1. First Water Hyacinth Observation

Respondents were asked to indicate the year they first observed the weed in the area to compare with the current status of the weed (in table 5). The responses on their first observation ranging from 2011 to 2018. Based on the data in table 5, below, 45.9% of the respondents indicated that they first observed water hyacinth in the area between 2011 and 2014 while 54.1% of the respondents confirmed that they first observed the weed between the year 2015 and 2018. This indicates that the number of respondents who first observed water hyacinth increased from time to time. Besides, Focus group discussants indicated that they first observed water hyacinth weed near the lake shore seven years ago. A research by Asmare (2017) also indicated that the presence of water hyacinth in Lake Tana was recognized in 2011. This implies that because the socio-economic and environmental impacts of water hyacinth in the area got bigger and attracting the attention of people from different areas, including media, the number of people interested to visit or observe water hyacinth in the area increased.

Table 5: Year at which water hyacinth first observed in the area

Year	C.F	%
2011	9	5.1
2012	11	6.2
2013	30	17.0
2014	31	17.6
2015	32	18.3
2016	26	14.8
2017	34	19.3
2018	3	1.7
Total	177	100.0

Source: Own survey 2019

In addition to their first time observation, respondents were asked where they think water hyacinth originally came from. Accordingly, the data in table 6, below indicate that 53.1% of the respondents replied the weed came from around Lake Tana area, 14.1% of them replied it was from Abroad, 6.8% of them replied it came from other water bodies in Ethiopia, 3.4% of them replied that they don't know and 22% of them replied "others".

Table 6: Respondents' perception on the origin of water hyacinth

Responses	F	%
Other water bodies in Ethiopia	12	6.8
Abroad	25	14.1
From Lake Tana area	94	53.1
Others *	39	22.0
I don't know	6	3.4
Missing	1	.6
Total	177	100.0

Source: Own survey 2019

Others*: Indicate evil spirit, Egyptians, some other Ethiopian Enemies.

The information gathered by interview revealed that water hyacinth was introduced in to Lake Tana in 2011/12. By the time, foreign construction experts were working in Dirma and Megech river banks and it was believed they brought the seed or living plant. On the other hand, the fishing net used by fishermen mostly came from Sudan and there was a thought that the seed came with the net or introduced when machineries and vehicles imported in to the area. However, the interviewees revealed that it was difficult to give the exact source of water hyacinth in Lake Tana. A study by Wassie et al, 2014 also indicated that the very source of this weed in Lake Tana is not well known. This indicates that the origin of water hyacinth in Lake Tana is not exactly known and needs to conduct more research on this issue as it will be very important to understand the climatic condition of its origin and compare to the lake area and prevent further infestation.

In order to determine whether there is a significant relationship between occupation and perception on the origin of water hyacinth, a Chi-square test was conducted (Table 7).

Table 7: Respondents' occupation and perception on origin of water hyacinth (cross tabulation)

Respondents' Occupation	F/%	perception on origin of water hyacinth					Total
		Other water bodies in Ethiopia	Abroad	From Lake Tana area	Others	I don't know	
Government employees	F	0	2	5	2	0	9
	%	0.0%	22.2%	55.6%	22.2%	0.0%	100.0%
Farmers	F	7	10	59	20	5	101
	%	6.9%	9.9%	58.4%	19.8%	5.0%	100.0%
Fishermen	F	1	8	13	4	0	26
	%	3.8%	30.8%	50.0%	15.4%	0.0%	100.0%
Water transport service	F	3	1	6	6	0	16
	%	18.8%	6.3%	37.5%	37.5%	0.0%	100.0%
Jobless	F	0	3	5	2	0	10
	%	0.0%	30.0%	50.0%	20.0%	0.0%	100.0%
Others	F	1	2	6	5	1	15
	%	6.7%	13.3%	40.0%	33.3%	6.7%	100.0%
Total	F	12	26	94	39	6	177
	%	6.8%	14.7%	53.1%	22.0%	3.4%	100.0%

As shown in table 7, the majority of participants in each occupation (Government employees 55.6%, Farmers 58.4%, Fishermen 50%, Water transporters 37.5%, Jobless 50%, and Others 40%) indicated that the origin of water hyacinth is from lake Tana area. To further test whether there is a relationship between occupation and the perception on the origin of water hyacinth, a chi-square test was run and the result was indicated below.

Table 8: Respondents’ occupation and perception on the origin of water hyacinth.

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	22.369	20	.321
Likelihood Ratio	23.136	20	.282
N of Valid Cases	177		

From table 8, the Chi-square test result indicated that the p-value is 0.321 which is greater than 0.05 (the alpha level associated with a 95% confidence level). This shows that the respondents’ occupation and the perception on origin of water hyacinth are independent of each other and that there is no statistically significant relationship between them.

4.2.2. Status of Water Hyacinth Expansion

In order to understand the current status of water hyacinth in Lake Tana and its trend of expansion over the years, respondents were asked to describe their observation. Accordingly, based on the data from table 9 below, 44.6% of the respondents indicated that the expansion of water hyacinth became severe, 36.7% indicated that the expansion became intermediate whereas 18.7% of them indicated that the expansion is minor. In addition, 82.7% of the focus group discussants indicated that they have observed water hyacinth expanding rapidly. They specifically revealed that the expansion of the weed was great during rainy season because it was pushed by storm from other parts of the lake. Similar observation by Solomon and Abeyou, (2018) indicated that for the last 6-7 years, water hyacinth has been occupying the Lake. This implies that water hyacinth is rapidly expanding to other parts of the Lake, creating socio-economic and environmental impacts in the area.

Table 9: Expansion rate of water hyacinth

Expansion Rate	F	%
Minor	33	18.7
Intermediate	65	36.7
Severe	79	44.6
Total	177	100.0

Source: Own survey 2019

In order to determine whether there is a significant perception difference between farmers and non-farmers on the expansion of water hyacinth, an independent t-test was conducted.

Table 10: Perception between farmers and non-farmers on the expansion of water hyacinth

Group Statistics				
Occupation of Participants	N	Mean	Std. Deviation	Std. Error Mean
Farmer	101	2.25	.78299	.07791
non-farmer	76	2.26	.71867	.08244

From the group statistics table 10, it is indicated that farmers have mean and standard deviation (M= 2.25; SD=.782) and non-farmers have also mean and standard deviation (M=2.26; SD=.718). Therefore, numerically both farmers and non-farmers have equal mean.

Table 11: Perception between farmers and non-farmers on the expansion of water hyacinth (Independent samples test)

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	1.68	.197	-.050	175	.960	-.00573	.11481	-.23233	.22087
Equal variances not assumed			-.051	168.182	.960	-.00573	.11343	-.22966	.21819

From the table 11, Levene’s Test for Equality of Variances indicated an F value of 1.68 and a significant value of 0.197. The latter is greater than 0.05 which is the standard alpha level. Therefore, we must accept the null hypothesis as there is no difference between the variance of the two samples. Furthermore, the t-test for Equality of Means indicated a t-value of -.050 and a 2-tailed *p*-value of .960, which is $p > 0.05$. Therefore, this study found that statistically there is no significant perception difference between farmers and non-farmers on the expansion of water hyacinth in the area.

4.3. The major socio-economic and environmental impacts of Water hyacinth

4.3.1. The economic impacts of water hyacinth

To determine the adverse impact of water hyacinth on the economic activities of the area, respondents were asked to explain the major impacts, as indicated in the table 12, below.

Table 12: The economic impacts of water hyacinth in the study area

Responses	F	%
Impact on Farming	52	29.4
Impact on Fishing	78	44.1
Impact on Water Transportation	17	9.6
Others	26	14.7
Missing	4	2.3
Total	177	100.0

Source: Own survey 2019

The data from table 12 revealed that 44.1% of the respondents indicated that water hyacinth created adverse impacts on fishing and 29.4% of them indicated that it created adverse impacts on farming. The impact of the weed on both fishing and farming account for 73.5%. The adverse impacts mentioned include, invasion of farm plots by the plant, a serious decline in fish stocks and production due to high concentration of hyacinth mats and depletion of oxygen, and also the weed mats block boat transportation on the lake. 14.7% of the respondents revealed “Others” to say the weed invasion replacing grass in the nearby area and leading to shortage of fodder for

cattle and shrinking of water as a resource. Similarly, one of the key informant interviewees explained the impact of the weed on farming as follow:

“Due to the nature of the weed and environmental context of the area, the problem is becoming severe. For instance, farm lands have been invaded by the weed, Rice, teff and wheat crops are affected. This influenced the productivity and volume of production in the area. Cattle productivity is being reduced, because when they feed the weed, they become sick, their excrement becomes thin and liquid, and their milk becomes tasteless”. (KII.01)

Concerning the adverse effects of water hyacinth in farming activities of the area, Focus Group Discussants revealed that many of the farmers engaged in hand removal of the weed repeatedly left behind their regular farming. During their participation they did not receive financial or in kind compensation for their time from the government. Another impact of the weed on the farm land, was the area previously occupied by the weed could not be used for crop production. Now, many households whose farm land found around the lake, faced further invasion of the weed especially during summer season because more hyacinth pushed by water storm and covered our farm land.

Based on physical observation the weed expanded in the area and occupied farm lands around the lakeshore. This implies that water hyacinth expansion increased in the lake and adjacent farmlands. This clearly shows the pressing threats of the weed on the livelihood of the people in the area.



Photo 1: Water hyacinth invaded-area in Achera kebele

Fishing is another economic activity carried out in the area which has been facing problems due to water hyacinth invasion. Respondents were asked to mention the major adverse effects that water hyacinth infestation caused on fishing activity. Accordingly, 70% of the respondents explained that because water hyacinth damaged fishing net and it has disrupted fishing in the lake and caused the reduction of fish production. The information obtained through focus group discussion revealed that water hyacinth expansion on the lake affected not only fishing and fish production but also the lake water itself and causing changes in the natural color of the fish. Asmare (2017) observed in this finding and revealed that after 2014, fishing has been exhausting due to the expansion of the weed in the area. Water hyacinth catches the fishing nets and push boats, making it difficult to fish and resulting in reduced fish catches. As fish production diminished, the income of those people whose economic activities rooted in fish production reduced and this would have an adverse effect on the livelihood of the communities around the lake and consequently affect the economy at large. Solomon (2017) indicated that the annual fish production potential in Lake Tana is estimated to be 13000 tons but its current annual production is only about 1000 tons. Recent studies indicated a serious of decline in fish stocks due to the spread of water hyacinth around fish spawning grounds. As a consequence, the lake has lost 75% of its fish production. This implies that water hyacinth invasion is affecting fish production in the area and leading to weakening of the income of the people involved in this activity.

Water hyacinth, as it invades, forming blankets over large bodies of water and creating impenetrable barriers and obstructing water transportation. The thick mats also block access to recreational areas and impacting the economies of communities that depend on it (Wassie et al, 2007). This observation was supported by the information obtained from one of the key informant interviewee that many young and adults in the local community were organized and engaged in water transportation services. However, due to barriers by water hyacinth, many of these people stopped working and became idle. From this we can understand that water hyacinth invasion in the area became an obstacle for water transportation and affected the livelihood of people engaged in this activity.

4.3.2. The social impacts of water hyacinth

The social impacts of water hyacinth have been manifested mainly in health condition of the local people. As one focus group discussant stated the health impacts of water hyacinth in the area as negatively impacted the health of lakeside communities. The weed provided shelter for mosquito and snakes. The expansion of the weed again turned the water in to green and polluted, making the supply unsuitable for drinking, sanitation and other domestic use.

From the above explanation, one can understand that the presence and infestation of water hyacinth caused adverse health impacts, mainly due to malaria during manual weed harvesting, related to supply and safety for drinking, sanitation and other domestic services in the area. This finding was also supported by Mujere (2015) as indicated that the weed has inflicted negative effects on the health status and well-being of many people who seek livelihood from the infested water.

4.3.3. Impacts of water hyacinth on Environment

The local environment is the first being affected by the infestation of water hyacinth. Focus group discussants also stated that the lake environment has been affected especially the water and native plants infected by it. In addition to this information, one of the key informant interviewees quoted was saying,

“The study area is among the localities which are adversely impacted more by the expansion of water hyacinth. Besides, pollution and bad smell in the water affected the quality of drinking water in the area, and we have feared that at one time the water would be remained out of use”. (KII.02)

These findings were also supported by Patel (2012) that water hyacinth weed out-competes the indigenous species due to its rapid reproductive ability, which poses a threat to aquatic biodiversity. This implies that the rapid infestation of water hyacinth in Lake Tana has disrupted the lake mainly the water and native plants are invaded by the weed. This also includes the adverse effects of the weed on aquatic life in the area.

4.3.4. Possible benefits of water hyacinth

As different researches in many countries indicate that even though water hyacinth causes various socio-economic and environmental problems, there are experiences that the plant has been turned to useful purpose before it became a problem. In Lake Tana water hyacinth has not been used for any beneficial purpose since it was not considered as useful. Respondents were asked whether they think water hyacinth has benefits. Accordingly, 7.9% of the respondents indicated that water hyacinth has benefit, mainly for cattle feed, 67.8% of the respondents indicated they don't think it is useful, and 23.7% of the respondents mentioned they don't know. As one of the key informant interviewee saying;

“Many farmers in the area faced shortage of cattle feed due to mostly absence of common grazing ground in the locality. As a result, the cattle were forced to use water hyacinth for feed. However, it has to be scientifically tested for better and more productive useage”. (KII.03)

Cattle herders were also shared their observation that their cattle were feeding the weed because they did not have alternatives. The above information was also supported by Ikiara (1999) that the weed has potential real economic value and it has been reported for instance that the weed can be used to produce biogas energy, purify water contaminated by raw sewage, produce manure and produce a substratum for the nourishment and breeding of some fish species. This

indicates that apart from its adverse effects, water hyacinth plant could be turned to useful product or purpose. This implies this it is clear that the possible benefit of water hyacinth was not well recognized by the local communities which could have been taken as a way to manage the expansion of the weed.

4.4. The current management practices of water hyacinth

4.4.1. Assessment of Legal and Institutional Framework for Water Hyacinth Management

Effective response measures depend mainly on the availability of national legislation that provides preventative as well as remedial measures. Such legislation should also establish clear institutional responsibilities. Accordingly, document review of the legal and institutional framework for the management practice of water hyacinth in Lake Tana was conducted.

As the foundation for all legislations at national level, the constitution of the country recognized the importance of the environmental protection and the need for its proper management, as EPA indicated. Afterwards, the legal framework relevant to the study topic, at national level, was the Environmental Policy of Ethiopia which was issued in 1997 to provide a framework for overall guidance in the conservation and sustainable utilization of the country's environmental resources. Moreover, the institution mandated to enforce the policy was the Ethiopian Environmental Protection Authority, established under proclamation No. 9/1995, now replaced by Environment, Forest and Climate Change Commission. The institution had legal structural arrangements from federal to the woreda level. However, review of the document revealed that the policy did not give due attention to water hyacinth in the country and the strategies lack clarity on how to manage the weed. Moreover, proclamation number 295/2002 was issued to establish environmental protection organs but it did not indicate specifically about the management of water hyacinth. At region level, Environment, Forest and Wildlife Protection and Development Authority of the Amhara Regional State organized under proclamation no. 232/2015, mandated to ensure the management and utilization of environmental resources in the context of sustainable development (EFWPDA, 2018). A year ago, the Regional State passed a new legislation in a bid to establish, a new body to oversee and control the spread of water hyacinth. This reveals that despite repeated changes in institutional arrangements, the policy as

well as subsequent strategy documents did not have due consideration about managing water hyacinth, perhaps the latest regional legislation. As one of the interviewee saying:

“We are trying to mobilize local communities and making efforts to manage the expansion and impacts of water hyacinth in the area only considering the usual understanding of Environmental Protection as well as on an ad hoc approach called-Green Your Garden Campaign: Protecting Lake Tana,- due to the fact that there are no specific policy provisions and strategies to deal with the problem”.
(KI0.04)

Regarding the legal framework for water resources management in Ethiopia, the Policy adopted essentially as an instrument for achieving the intended goals and objectives in the sector (MoWR, 1999). In the part of the Water Resource Management Policy dealing with general water resources management, the major relevant provisions included were: enhancing integrated and comprehensive management of water resources that avoids a fragmented approach; recognized water as a scarce and vital socio-economic resource and to be managed on a strategic planning basis; ensure that water resources management is compatible and integrated with other natural resources, the need for intersectoral coordination at all levels. In addition, the Ethiopian Water Resources Management Proclamation, issued in March 2000 (Proclamation No.197/2000), is the basic legal instrument governing the management, planning, utilization and protection of water resources in Ethiopia. Hence, assessment of the legal documents indicated that they contained some relevant provisions that need to be considered for effective management of the water resources of the country.

Respondents were asked whether lack of legal enforcement was the reason for failure to manage water hyacinth in the area. Accordingly, 37% of the respondents replied “Yes”, 36% replied “I don’t know”, 25%) of them replied “I don’t think it is useful”, and the remaining 1%) of the respondents replied “May be”.

Regarding biodiversity, the legal framework relevant to the study topic was National Policy on Biodiversity Conservation and Research which was issued in 1998, having an institution named Ethiopian Biodiversity Institute mandated to undertake conservation and promote development

and sustainable utilization of the country's biological resources, microbial genetic resources as well as associated community knowledge and the ecosystems. Moreover, both the federal and regional conservation strategies have dealt with the broad spectrum of issues relating to the environment. There were some statements indicated in the federal conservation strategy about aquatic ecosystem and the threats there but nothing was mentioned about water hyacinth in the National policy document. Hence, from the assessment we could understand that the legal frameworks were not inclusive of issues related to water hyacinth.

In spite of general provisions given by the Federal Democratic Republic Ethiopia constitution on the importance of the environmental protection and the need for its proper management, assessment of the aforementioned policies the respective strategies of those policies did not incorporate clear provisions about water hyacinth on how to manage the weed. As Ethiopian Economics Association (2011) indicated this is because of less consideration given to taking evidences form grassroots, the absence of informed debate among the various stakeholders to feed into policy formulation, and weak networking between the different stakeholders in policy formulation and implementation. Moreover, there were no experiences to revise the national policies and strategies to accommodate the dynamism prevailing nationally and at international level. As a result, except some relevant provision indicated by water resource management policy, other relevant policies were silent on the management of aquatic alien species such as water hyacinth.

4.4.2. Practices of Water hyacinth Management

Water hyacinth is very difficult to eradicate once established. The goal of most management efforts is therefore to minimize economic costs and ecological damage. Recent literature on the management of water hyacinth focuses on techniques to remove the weed (Villamagna & Murphy, 2009). In Lake Tana, fragmented efforts have been done to control water hyacinth infestation. These efforts, according to Addis Standard (2017) were mainly focused on mobilizing affected farming communities to uproot and dispose the weed manually.

In order to understand the efforts made by the government to control the weed in the area, respondents were asked to reveal the extent of government participation. Accordingly, 51% of

the respondents indicated that the effort made by the government was inadequate. They also mentioned that at the beginning local government bodies made efforts to raise awareness and mobilize local communities and some secondary school students for hand removal of the weed but the effort did not continue as it was. In addition, respondents were also asked to state their opinion on the efforts made by the local community. As a result, 87% of the respondents indicated that the effort made by the local communities were encouraging. They further elaborated that members of the local community did a lot to reduce the weed through hand removal; especially, farmers spent much of their time doing the removal. Respondents were also asked whether non-governmental organizations made efforts in the management of water hyacinth in the area. Therefore, 43% of the respondents indicated that they don't know, 28% of the respondents indicated that they only know that many young people came from outside the area and repeatedly participated in hand removal campaign. Only 7% of the respondents indicated that they heard some machineries were offered by some donor individuals and researchers. In addition, the information obtained from interview participants indicated that the local community made much effort for the last 5 to 6 years, to the extent that farmers devoted their time, energy and health. However, starting from a couple of years, members of the local communities have not been active to engage in the removal because they did not get any response from the government. With regard to government effort, the interviewees indicated that government made inconsistent effort to mobilize local community on the one hand and facilitating the use of machinery (when they are damaged) for weed removal on the other hand. However, the effort has been weakened, except conducting international experience sharing visits and trainings at region level that have not been applied yet. Individuals- few tried to contribute by importing machinery while NGOs were not approached by the government to support the efforts.

In addition to the above findings, Yihun & Wondwossen (2017) also supported that the efforts that have been made to control water hyacinth in Lake Tana were inadequate as compared to the scale of the problem. From the above information and explanations we could understand that the efforts to control the expansion of water hyacinth in the lake involved mainly hand removal of the weed by members of local communities, with some effort to use harvesting machine. This implies that the effort to manage water hyacinth infestation in Lake Tana by concerned actors is inadequate and even the efforts is disorganized to control sustainably.

4.5. The major challenges of managing water hyacinth in Lake Tana

Due to its rapid growth rate, its ability to successfully compete with other aquatic plants, and its ease of propagation, water hyacinth is causing adverse environmental and socio-economic effects in lake Tana area. The Amhara regional government named it as the most dangerous weed affecting the Lake. In order to tackle the problem efforts have been underway by local communities and a government body despite the infestation has not been halted. This is also supported by Asmare (2017) that although a tremendous amount of human labor, time and money has been utilized each year by both surrounding community and government, its coverage continues to escalate.

From the above information it is possible to understand that the efforts to manage the infestation of water hyacinth in the area are not fruitful. This also shows that there are challenges to manage the problem well. The challenges were a combination of several factors. The major ones identified from the questionnaire respondents, focus group discussants, key informant interviewees and also from related literature, including researcher's observation, are indicated in the following sub-section:

4.5.1. Lack of strong Institutional Capacity and Legal framework

The result from the assessment of relevant policy and strategy documents revealed that there were no specifically indicated legal frameworks at national level about water hyacinth management approaches. This gap was also manifested at regional level. As a result, water hyacinth management practices were not guided by explicit legal context. The information from key informant interview also revealed that lack of relevant legal framework became one of the challenges to guide water hyacinth removal operation. On the other hand, lack of strong (legally, financially and technically) and independent institutional set up to lead (plan, execute and monitor progresses) water hyacinth management practices and effort was the other challenge. Even the existing operational system at region and subsidiary level faced capacity deficit. The above findings were supported by Yihun & Wondwossen (2017), indicated that the institutions are marked by poor mobilization of resources and lack of coordination and decisive leadership.

Respondents were asked to give replies on the major challenges that affect the management of water hyacinth in Lake Tana. Accordingly, 86% of the respondents indicated that Lack strong institution in terms of the required financial resources, manpower and technical expertise. Moreover, 10.7% of the respondents gave their response as “Others”- such as Government’s lack of attention or commitment, lack of good governance, and because the management approach was not participatory.

The information obtained from key informant interviewees indicated that Regional government has been mobilizing much money but they are not purposely utilizing for the weed controlling effort. Even the Amhara Region- Environment, Forest & Wildlife Protection & Development Authority has not allowed other regional government offices and organizations to participate in the issue. Moreover, lack of strong institutional capacity also affected data management, monitoring, evaluation and lesson learnt. From this we can understand that the above weakness led to failure to ensure institutional transparency and accountability for the expansion of the weed and damage of the Lake.

In order to determine whether there is a significant relationship between occupation of respondents and perception on challenges of managing water hyacinth, a Chi-square test was conducted. Besides, cross-tabulation between the variables was indicated below.

Table 13: Respondents' occupation and perception on challenges of managing water hyacinth
(Cross tabulation)

Occupation of Respondents	F/%	Perception on Challenges of Managing Water hyacinth					Total
		Skills	Knowledge	Finance	All	others	
Government employee	F	0	1	3	5	0	9
	%	0.0%	11.1%	33.3%	55.6%	0.0%	100.0%
Farmer	F	5	13	18	52	13	101
	%	5.0%	12.9%	17.8%	51.5%	12.9%	100.0%
Fishermen	F	0	2	4	13	7	26
	%	0.0%	7.7%	15.4%	50.0%	26.9%	100.0%
Water transport service	F	0	5	0	9	2	16
	%	0.0%	31.3%	0.0%	56.3%	12.5%	100.0%
Jobless	F	0	1	1	6	2	10
	%	0.0%	10.0%	10.0%	60.0%	20.0%	100.0%
Others	F	0	1	0	11	3	15
	%	0.0%	6.7%	0.0%	73.3%	20.0%	100.0%
Total	F	5	23	26	96	27	177
	%	2.8%	13.0%	14.7%	54.2%	15.3%	100.0%

As shown in table 13, the majority of respondents in each occupation (Government employees 55.6%, Farmers 51.5%, Fishermen 50%, Water transporters 56.3%, Jobless 60%, and Others 73.3%) indicated that lack of skills, knowledge and finance are the major challenges water hyacinth in the area. To further test whether there is a relationship between respondents' occupation and the perception on the challenges of managing water hyacinth, a chi-square test was run and the result was indicated below.

Table 14: Respondents' occupation and perception on the challenges of managing water hyacinth (Chi-Square Test)

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	22.332	20	.323
Likelihood Ratio	28.008	20	.109
N of Valid Cases	177		

From table 14, the Chi-square test result indicated that the p-value is 0.323 which is greater than 0.05 (the alpha level associated with a 95% confidence level). This shows that the participants' occupation and perception on the challenges of managing water hyacinth are independent of each other and that there is no statistically significant relationship between them.

4.5.2. Lack of appropriate technology to apply to manage the weed

Understanding the depth of the problem and prevailing efforts is important to inform decision-makers on taking alternative measures. This requires applying relevant and environment-friendly technology so as to give lasting solution. However, an assessment of government reports indicated that there are no relevant technologies so far utilized to contribute the weed management efforts. As one of the key informant interviewees saying;

“As far as the application of relevant weed control technologies in the area, I have no official information except, some officials in events and meetings, indicated that they are making some efforts to conduct biological control method to apply in Lake Tana. However, these officials repeatedly told us the same thing for the last 4 to 5 years while nothing changed. What I can tell you is the weed infestation is expanding and our dependent on hand removal and rarely use of machinery did not bring lasting solution”. (KII.05)

This implies that lack of application of relevant technology contributed to failure to effectively manage the weed and reduce the risk it posed in the area.

4.5.3. Low concern of Federal and Regional Governments

As the weed expanded and posing threat, the local communities mainly have tried the manual removal of the weed but with little success due partly lack of continuous policy and management support by governments. This indicates that government was not much concerned about using relevant control method, like biological approach. Respondents were asked about the major challenges of managing water hyacinth in the Lake. Accordingly, 10.7% of the respondents replied: lack of attention or commitment by the government, lack of good governance, and

because the management approach was not participatory of concerned stakeholders for better performance.

Although the Federal level government institutions (such as Ministry of Environment, Forest and Climate Change, Ministry of Water, Irrigation and Electricity, and Ministry of Agriculture and Natural Resource Development) are, in one way or another, involved in the sustainable management and utilization of the country's natural resources, their silence while the largest lake in the country is mired in a grave environmental crisis raises questions. Their inaction casts doubt on the commitment of the federal government to rescue the lake (Yihun & Wondwossen, 2017). Besides, regional government lacking care and follow up to projects implemented on the lakeshore, haphazardly.

As one of the manifestations of carelessness and low attention given by the government to the issue in one of the interviewee, saying:

“In some cases, government officials at region level give wrong information, without further elaboration, to the public that the weed cannot be eradicated which resulted in loss of motivation and hope by local communities, and on the contrary, they send false report- informing that the weed expansion is decreasing, that was compiled during dry season when water hyacinth expansion not as much as rainy season”(KII016).

From this one can understand that there was lack of commitment by concerned government bodies to play their roles in coordinating partners, supporting and managing the problem in a way that will stop the infestation of water hyacinth and cure the existing problem in the area.

4.5.4. Declining participation of local communities on manual removal method

Studies indicate that efforts mainly physical removal of water hyacinth have been made in Lake Tana. As Mahder (2017) indicated that in the past five years, manual labor invested in an effort to eradicate the weed is valued at more than \$1.5 million. However, the information obtained from the focus group discussants and key informant interview, indicated that the participation of local community in hand removal campaign declined since a couple of years. The reason for this,

as indicated, was their sacrifice of time, energy and livelihood did not get compensation and support from the government side. Specifically, lack of financial incentive and protective facilities and equipment. As InfoNile, (2018) also indicated there are two main challenges with manual removal method - first, the Regional Environment, Forest and Wildlife Development Authority is not interested to make consultations to local community on their concern to alleviate the problem. Second- the removal works of water hyacinth are being done mostly by volunteer farmers that is the Authority doesn't pay incentives for motivation". Hence, according to the Authority, as of yet there is no tested and functional method to control the weed. From the above discussions we can understand that the declining of participation by members of the local community, mainly because of lack of support from concerned government bodies became one of the challenges of managing water hyacinth infestation in Lake Tana.

Chapter V

Conclusion and Recommendations

5.1. Conclusion

In Lake Tana Water hyacinth created serious problem mainly on the environment and socio-economic activities, and continues to escalate despite efforts. The main objective of the study focused on the challenges of managing the impacts of water hyacinth in Lake Tana, with reference to Achera and Adisge Kebeles. Based on the major findings of the study, conclusions were drawn.

The study revealed that water hyacinth expansion in the lake has increased since its first appearance in the Lake. Therefore, this study concluded that the efforts to control the expansion were inadequate. The study also identified the major adverse effects of water hyacinth on the natural environment mainly-on lake biodiversity, and socio-economic activities in the area. Therefore, this study concluded that the efforts to manage the expansion of the weed were not effective. The study identified that the current weed management approach focused mainly on hand removal practices which mainly involved mobilization of local communities. Therefore, this study concluded that the current water hyacinth management efforts were dependent on manual removal of the weed which involved local communities. This shows that other weed management practices were not applied and government has not played its role properly.

The study identified that the major challenges of managing water hyacinth in Lake Tana are: lack of government institutional capacity to properly function and Legal framework to guide, lack of relevant technology to apply to manage the weed, low concern given by the Federal and Regional Governments, and declining participation of local communities on manual removal method. Therefore, this study concluded that the major challenges of managing water hyacinth infestation in Lake Tana are government's low attention to establish functional institution that is guided by legal framework and apply relevant technology that could fit to the context and properly organize and utilize manual efforts.

5.2. Recommendation

The findings of the study indicated that the threat that water hyacinth posing on Lake Tana is already a real one. The natural environment is facing crisis and the economic and social consequences may soon become extremely serious. The existing methods of managing water hyacinth infestation are not successful. Hence, the study put forward the following recommendations to manage water hyacinth in the study area in a sustainable way:

5.2.1. Short-term recommendations

- **Facilitate National Consultative Meeting**

The government needs to facilitate national consultative meeting with multi-stakeholder committee: such as representatives from academic institutions & research centers, Civil Society Organizations, Private sectors, government authorities and institutions to share their experiences on searching for immediate and long-term solutions and prospects of the problem.

- **Support and Strengthen Current Efforts**

Each day that passes without taking meaningful action against the weed is possibly disastrous for lake Tana. This is because of the aggressive proliferation of the weed and viability of its seeds for long time without decay. Therefore, even though the existing method, mainly manual control of the weed, have often been insufficient, it is imperative for the government and other concerned bodies to support those who are involved and strengthen the effort in all aspects. For instance, particular attention should be given to community mobilization, access to information, and coordination of efforts. Mechanical control of the weed has to be functional. Besides, use of volunteers, as weed control is often very labor-intensive and thus, depending on the local costs, very expensive. Hence, calling people for volunteer participation, using experienced supervisors, support the existing efforts since they will be proud to be part of a successful campaign. If the public can actually be involved, people may start to identify with the project.

5.2.2. Medium & Long-term Recommendations

- **Establish appropriate legal Framework and Institution**

For effective management of water-hyacinth infestation, appropriate policies and strategies at federal and regional levels need to be formulated and be operational to control the infestation. The legal framework helps to avoid overlaps of responsibilities or unclear jurisdictions among competing interests of government institutions for implementation at all levels. Moreover, independent institution has to be established with appropriate duties and responsibilities, including the capacity to manage the problem in accordance with the provisions of the relevant law and in cooperation with other competent institutions. Hence, these measures help to resolve the competing interests of the various stakeholders of the lake during project planning.

- **Apply appropriate technology to manage the weed**

The government needs to facilitate and support the application of relevant technologies based on scientific researches that will help lasting solution. Besides, government needs to approach local communities on indigenous and cultural solutions for the problem that will complement the scientific one.

- **Apply integrated controlling approach**

Application of Integrated controlling method: the major water hyacinth control effort currently underway in Lake Tana is manual method. However, depending on the nature of the ecosystem, species richness, and climatic regions, it is possible to apply a combination of management options, such as, chemical, mechanical and biological controls where biological control is believed to have long-term solution to the weed problem. Hence, application of integrated management method provides effective and acceptable control. Because, the integration of methods based on ecological research, regular monitoring, and co-ordination will help to achieve the best results in managing the weed.

- **Apply Integrated Watershed Management**

The ultimate goal of integrated watershed management is to improve the quality of the environment and livelihood of the people around. Hence, in order to control water hyacinth expansion in Lake Tana, the entire watershed management should be considered and key stakeholders in the catchment need to be engaged in the control efforts – both in terms of addressing water quality in the system, such as controlling waste disposal from the surrounding service areas, and in terms of all-rounded support to the control water hyacinth infestations.

- **Use for Productive purpose**

Water hyacinth is potentially useful to man. The possible application of the weed include: bio-gas production, livestock feed, bin-fertilizer, waste water treatment and as raw material for industries. Therefore, concerned bodies have to conduct relevant researches that will enable turning water hyacinth in to useful product. This would not only manage its proliferation but also help to alleviate income poverty and empower the community.

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Appendix A

Addis Ababa University
College of Development Studies
Department of Environment and Sustainable Development

Questionnaire to be filled by Local Community

Date _____

Name of study Area _____

Dear Respondents,

This questionnaire is prepared to collect data for a research being undertaken entitled “*The challenges of managing the impact of water hyacinth in Lake Tana, (Achera and Adisge Kebeles of Dembia woreda), Central Gondar Zone*”

The information will be used only for academic purpose.

Thank you in advance for your time & cooperation!

Part I: Household Information

Instruction: Dear respondent please encircle your response for each question and write also your response to the questions on the spaces provided.

No.	Questions	Response
1	Sex	1. Male 2. Female
2	Age	1. Below 18 years 2. 18 – 29 years 3. 30 – 59 years 4. 60 years and above
3	Educational status	1. Illiterate 2. Can read & write only

		3.	Primary education
		4.	Secondary education
		5.	Certificate/TVET/Diploma
		6.	First Degree and above
4	Occupation	1.	Government employee
		2.	Farmer
		3.	Fishing activity
		4.	Water transport service
		5.	Without any job
		6.	Other (please mention)_____
5	Household size	1.	Single
		2.	2 - 4 members
		3.	5 – 7 members
		4.	Above 7 members

Part II: The status of water hyacinth in the area:

Direction: the following questions are about the status of water hyacinth infestation in the area.

Thus, please give your response to each question.

1. When did you first observe water hyacinth weed in the lake? Mention the year and month:

2. Where do you think is water hyacinth originally come from?

1/ From other water bodies within the country 2/ Abroad
 3/ From the lake area 4/ I don't Know 5/ Other, if any ____

3. How do you describe the expansion of water hyacinth weed on the Lake?

4. Do you think there is a change of Lake Biodiversity due to water hyacinth infestation?

1/Yes 2/ No 3/ other (please mention) _____ 4/ I don't Know

5. If your answer for question number 4 is “Yes”, what do you think is the reason?

6. How do you categorize the extent of water hyacinth spread over the last five years in the area?

1/ Minor - smaller in amount, extent, or size; lesser in seriousness or danger, one that is lesser in comparison with others of the same

2/ Intermediate - occurring or situated between two points, extremes, places, etc; in between.

3/ Severe - Serious in appearance or stern; critical or dangerous in manner

Part III: The major impacts of water hyacinth in the area

Direction: the following questions are about the status of water hyacinth in the area. Thus, please give your response to each question.

1. What are the major adverse economic effects (e.g. on fishing, farming) of water hyacinth in the area?

2. What are the major adverse social effects (e.g. impact on human health, blocking water transportation) of water hyacinth in the area?

3. What are the major adverse effects of water hyacinth on the local environment (e.g. on quality and quantity of water, aquatic life, air)?

4. Do you think there is community awareness about the impact of water hyacinth infestation in the area?

5. Do you think lack of enforcement of relevant legislation for water hyacinth management contributed for its current effect?

Part IV: The current water hyacinth management practice in the area:

Direction: the following questions are about the status of water hyacinth in the area. Thus, please give your response to each question.

1. How do you describe the efforts made by government organizations at different level to manage water hyacinth infestation in the area?

2. How do you describe the contribution of non-governmental organizations (Civil Society organizations and Private Sectors) to manage water hyacinth infestation in the area?

3. How do you describe the contribution of local community to manage water hyacinth infestation in the area?

4. How do you evaluate the overall result brought by the efforts to manage water hyacinth infestation in the area?

5. Do you think water hyacinth has benefits?

6. If your answer for question number 5 is “Yes”, for what purpose do you use?

Part V: The major challenges of managing water hyacinth in the area

Direction: the following questions are about the status of water hyacinth in the area.

Therefore, please give your response to each question.

1. What do you think are the major challenges of managing water hyacinth infestation in the area?

1/ Skills 2/ Knowledge 3/ Financial 4/ All

5/ Other (please mention) _____

2. What do you think are government, academician and researchers should do to address these challenges? Elaborate _____

3. What approaches do you suggest to be applied for effective management of water hyacinth infestation?

Thank you very much for your time!

Appendix B

Key Informant Interview Schedule for Government Officials and Experts

Name _____

Position _____

Date _____

Name of study Area _____

Objective: The interview is intended to acquire information required in the study entitled “*The challenges of managing the impact of water hyacinth in Lake Tana, (Achera and Adisge Kebeles of Dembia woreda), Central Gondar Zone*” where you have been selected to help out provide the information. Your experience, knowledge and suggestions are very important.

Therefore, I am kindly requesting to answer questions pertaining to this study.

Contact Name:	Date:
Profession:	
Institution:	
Address: Telephone	Email:

Key Informant Interview Questions: prepared for Government experts and heads of departments at woreda Zone and Region level.

1. How do you think water hyacinth introduced first in to the lake?
2. Which legal framework and institution guide your intervention to manage water hyacinth in the area?
3. How do you describe the current efforts by the government and community to manage water hyacinth in the area?
4. How do you express the commitment of government to manage the problem? Have you applied relevant technology to management the problem?

5. How do you evaluate the institutional capacity (finance, manpower and materials/facilities) and legal framework of concerned government bodies to manage water hyacinth infestation in the area?
6. How do you describe the overall economic, social and environmental damages brought by water hyacinth in the area?
7. What do you think are the major challenges to effectively manage water hyacinth infestation in the area?
8. What method/approach do you suggest to make water hyacinth management effective?

Thank you very much for your time!

Appendix C

Date _____

Name of study Area _____

Focus Group Discussion with local farmers, persons engaged in water transportation and fisher men.

1. How do you describe the introduction and expansion of water hyacinth in to the area?
2. Do you think the local community is aware of the adverse effects of water hyacinth in the area?
3. Do you think water hyacinth infestation has brought negative effects on the socio-economic and environment of the area? What do you think are the negative effects?
4. Do you think there are appropriate policies and strategies to manage water hyacinth in the area? Do you think the community is aware of these?
5. What do you think are the major challenges to effectively manage water hyacinth infestation in the area?
6. What approach do you suggest to be applied for effective management of water hyacinth in the area?

Thank you very much for your time!

Appendix D

Informed Consent for FGD Participation

Researcher: Abeje Hiruy (GSE/6040/09)

Phone: +2519-11443565

Purpose

This study investigates the challenges of managing water hyacinth in Lake Tana, (Achera and Adisge Kebeles) Central Gondar Zone. As part of this study you will be asked to participate in a focus group and answer structured and open-ended questions. This study will take approximately 45 minutes.

Participants' Rights

I understand that my responses will be kept in the strictest of confidence and will be available only to the researcher. No one will be able to identify me when the results are reported and my name will not appear anywhere in the written report. Please do not share other people's identities or responses from the focus group with others to maintain the anonymity of the participants outside of the focus group. I also understand that I may skip any questions or tasks that I do not wish to answer or complete. I understand that the consent form will be kept separate from the data records to ensure confidentiality. I may choose not to participate or withdraw at any time during the study without penalty. I agree to have my verbal responses tape-recorded and transcribed for further analysis with the understanding that my responses will not be linked to me personally in any way. After the transcription is completed, the tape recordings will be destroyed.

I understand that upon completion, I will be given full explanation of the study. I understand that I am participating in a study of my own free will.

Consent to Participate

I acknowledge that I am at least eighteen years old, and that I understand my rights as a research participant as outlined above. I acknowledge that my participation is fully voluntary.

Name: _____

Signature: _____

Date: _____