Status and ecosystem functions of *Cyperus papyrus* in Tikur Wuha wetland, Southern Ethiopia

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June, 2018

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A Thesis submitted to The Department of Plant Biology and Biodiversity Management Presented in Partial Fulfilment of the Requirements for the Degree of Master of Science in Plant Biology and Biodiversity Management

Addis Ababa University
Addis Ababa, Ethiopia
June, 2018

ADDIS ABABA UNIVERSITY

GRADUATE PROGRAMMES

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Abstract

Title: Status and ecosystem functions of Cyperus papyrus in Tikur Wuha wetland, Southern Ethiopia

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Cyperus papyrus, commonly known as papyrus called Filla by the local people in the current study area is one of the most important macrophyte species growing in the wetlands of tropical and sub-tropical countries. The aim of this study was to investigate Status and Ecosystem services of Cyperus papyrus in Tikur Wuha wetland with special emphasis on its ecological functions, population status, and its ethnobotanical uses in Tikur Wuha wetland in Southern Ethiopia located upstream of Lake Hawassa. Prevailing physical, chemical and climatic parameters of wetland was explored to check the water purification role of Cyperus papyrus. Current population status was studied using two transect lines systematically laid along right and left side of Tikur Wuha wetland to count population of Cyperus papyrus. Along the transect lines successive quadrants of (5mx5m) for matured plants and (1mx1m) for young shoots of 100m were laid. Physico-chemical data was also collected from three sites with high, low and no Cyperus papyrus populated area and water quality assessments were analysed for determination of role of Cyperus papyrus in water purification using Temperature, PH, Dissolved oxygen, Conductivity, Turbidity, Total Nitrogen, Total Phosphorous and heavy metals analysis. Moreover, local uses were assessed by using well established ethnobotanical data collection and analysis tools such as market survey, key informants and preference ranking. In addition, the economic and market value of Cyperus papyrus were collected using semi-structured questionnaire. The result indicated that the number mature of Cyperus papyrus was generally higher than the young shoots except few area. The results of physico-chemical studies also showed that high C papyrus populated areas contain low amount of Temperature, PH, Conductivity, Turbidity, and also high potential to uptake the Nitrogen, phosphorous and heavy metals. The result was generalized by using table and figure. This investigation showed that current status of C. papyrus is very hard to decide even the presence in the next coming years that's why the destruction is very high but the conservation management approach is very low so the responsible stakeholders should have to enforce the policies become applied, creating awareness and make the local people, the owner of the natural environment and let them benefited from the resource.

Key words:-*Cyperus papyrus*, ethnobotany, Physico-chemical, wetland.

Table of contents

Acknowledgment

Many people contributed to the completion of this work. I am happy to convey special thanks to my advisors Dr Bikila Warkineh, Professor Sileshi Nemomissa and Dr Ermias Lulekal for their tireless efforts in directing and correcting this thesis from the very start up to the end and I greatly acknowledge their admirable patience for giving me a chance to fulfil the thesis work.

My sincere thanks go to Addis Ababa University Female Scholarship program, Bishaan Gurraachaa (Tikur Wuha) city administration, Ethiopia National Meteorological Agency also deeply acknowledged for delivering climate data of the study area. I would like to thank local peoples of Bishaan Gurraachaa and Hawassa, farmers, fisheries, sellers and elders for their collaboration to participate as interviewees in my research.

I would like to thank AAU and Department of Plant Biology and Biodiversity Management staff, Department of Zoology for delivering logistic materials and technical support for field activities.

I am indeed grateful to my family, friends, and class mates for their persistent love, patience, support, continuous moral and encouragement during my postgraduate study. I wish if I could list all individuals who stood by my side, but I simply forward my heartfelt thanks and appreciation.

God bless you all!!

List of figures

List of table

List of Appendices

Acronyms

a.m.s.l…….. Meter above sea level

APHA…….American Public Health Association

BOD…… Biological Oxygen Demand

EPA……Environmental Protection Authority

MPL…… Maximum Permissible Level

NTU…… Nephelometric Turbidity Units

SNNPR….. Southern Nations, Nationalities and People Region

WHO……. World Health Organization

µs/cm…….. micro/ millisiemens per centimeter

CHAPTER ONE

1. Introduction

Article 1.1 of the Ramsar Convention (www.ramsar.org) defines wetlands as areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres. In addition, the convention in Article 2.1 provides that wetlands may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water not deeper than six meters at low tide lying within the wetlands. As scientific understanding of wetlands has increased, more subtle goods and services have become apparent. Wetlands have been described both as "the kidneys of the landscape", because of the functions they can perform in the hydrological and chemical cycles, and as "biological supermarkets" because of the extensive food webs and rich biodiversity they support (Tadessse Amsalu and Solomon Addisu, 2014).

Wetlands continue to decline globally both in area and in quality. As a result, the ecosystem services that wetlands provide to society are diminishing. The millennium ecosystem assessment (MEA 2005) reported that more than 50% of the area of certain wetland types had been lost during the 20th century. Losses in natural wetlands continue in the 21st century at a much (3.7 times) faster rate of wetland loss (Davidson, 2014). Africa's wetland ecosystems are estimated to cover more than 131 million hectares. They deliver a wide range of ecosystem services that contribute to human well-being such as nutrition, water supply and purification, climate and flood regulation, coastal protection, feeding and nesting sites for animals, recreational opportunities and tourism. The largest wetlands in the African continent include the Okavango Delta, the Sudd in the Upper Nile, Lake Victoria basin and Lake Chad basin and the floodplains and deltas of the Congo and Niger (http://wetlands.org.africa).

Ethiopian wetlands are estimated to cover about 2% of the country's land coverage. Despite their small area coverage, wetlands in Ethiopia are among the most productive ecosystems, and have immense economic, social, and environmental benefits (Tadessse Amsalu *et al.*, 2014). In wetter part of the country, for example, Illubabor, swamplands are most common accounting up to 5% of the area in the highlands. Similarly, other highlands of the Western, South, and Southwest of the country including Jimma, Wollega and Illubabor Zones of Oromia Region,

Keffa-Sheka of South Region as well as the low-lying regions of Ethiopia have considerable area of wetlands (swamps and flood plains) (EBI, 2016). Ethiopia is often referred to as the water tower of Africa creating an extensive wetland system throughout the country. The wide diversity of landscapes of the Ethiopian Rift Valley (ERV) and ecosystems comprise extensive biodiversity-rich wetlands. At the same time the ERV is one of the environmentally vulnerable areas in Ethiopia**(**Teklu Gebretsadik *et al.*, 2017.)

In Ethiopia, *Cyperus papyrus* is one of the native and most important plants (Kumar, 2011). *C.papyrus*, commonly called papyrus or paper plant, is a member of the Cyperaceae. The family has about 90 genera and more than 4,000 species, which are for a large part perennial rhizomatous herbs growing in wetland ecosystems of tropics and sub tropics (Lim, 2016). Papyrus (*Cyperus papyrus* L.) is an emergent, C4 photosynthetic sedge which is native to the wetlands, river valleys and lakes of central, eastern and southern Africa and has been successfully introduced to Italy, United States and India (Terer *et al*., 2012). *C. papyrus* is one of the most productive and fast-growing perennial sedge (Muthuri, *et al*., 1988). Papyrus is the largest sedge and attains a height of 3-4m, but can attain 10 m in high altitude sites (Terer*et al*., 2012). Currently, it is widely used in Africa including Ethiopia for economic purposes. (Simpson and Inglis, 2001; Katondo, 2004; Terer*et al*., 2012; Mburu*et al*., 2015; Lim, 2016).

In addition to its economic benefits, papyrus has also played innumerable role in ecological aspects. From an ecological perspective, papyrus traps (filters) pollutants such as nutrients, heavy metals and sediments from the catchments, which could otherwise lead to eutrophication of the water bodies (Abe, *et al*., 1997; Kyambadde, 2005; YezbieKassa and SeyoumMengistou 2014). Papyrus is also important for breeding, nesting and feeding sites for fish, birds, amphibians and invertebrates and has been recognized for its contribution to ecosystem functions and services (Jones *et al*., 2016). Despite its uses for innumerable functions and services for human wellbeing, the species is adversely affected by anthropogenic activities such as overexploitation, draining of wetlands for the purpose of expanding farmland and other developmental activities and overgrazing by livestock (Maclean, *et al*. 2006; Owino and Ryan, 2006; Terer, *et al*., 2012).

Compared to other plant species, little is known about the ecology, conservation status and utilization of *Cyperus papyrus* in Ethiopia. On the other hand, the species occurs in different parts of the country (Lye, 1997; GetachewNigatu, 2005; GirumTamire and SeyoumMengistou, 2012). According to GetachewNigatu (2005) and AssefaTessema*et al*. (2013), papyrus plays

vital economic roles for local communities in Ethiopia. The local communities living near the papyrus swamps have used it for different purposes for a long period of time. However currently the population of papyrus has declined due to unsustainable uses such as over exploitation, over grazing, burning and draining of papyrus swamps. As a result, its range and extent has greatly reduced.

Therefore, the objectives of this study are investigate the status and ecosystem functions of *Cyperus papyrus* in Wetland of (Tikur Wuha), Bishaan Gurraachaa Southern Ethiopia, and to study its local ethnobotanical uses.

1.1 Statement of the problem

Wetlands are among the most productive ecosystems on earth and protection of threatened natural wetlands and preservation of its biodiversity has received increasing attention globally. However wetlands and their resources in Ethiopia are still facing many problems. High population densities within the catchments of the Ethiopian Rift Valley Lakes and in the highlands have been associated with a series of deleterious trends, in particular those arising from the clearance of vegetation for agriculture and overgrazing (Seleshi Bekele, 2001). Some of the key challenges to the wetlands are intensive use of land in the buffer zones for crop production, land loss due to deforestation in the watershed, and eutrophication by nutrients from agricultural fields. Overgrazing of lakeshore vegetation by livestock and overharvesting particular plant species for the construction of traditional boat, clearance of lakeshore vegetation and trampling due to fishing activities and deforestation in the watershed are also the main threats to the wetlands (Seleshi Bekele, 2001).

Despite their importance for the maintenance of biodiversity, wetlands and their resources (vegetation in particular) in Ethiopia have been barely investigated and their previous documentation was extremely limited. In addition to this, no comparative study was undertaken on wetland vegetation. Only limited plant community studies have been undertaken on isolated wetlands of Illubabor (Zerihun Woldu and Kumlachew Yeshitila, 2003), on Awash reverine vegetation (Mitiku Tikssa *et al*., 2010) and semi-wetland of Cheffa area, South Wello (Bayafers Tamene *et al.*, 2000).Most of the previous researches conducted on wetlands of southwest Ethiopia have focused on wetland management and policy implications (Afework Hailu *et al*., 2003). On the other hand, Lake Tikur Wuha whose area was 11.3 km^2 in 1973 and has totally vanished and transformed into mud-flat and grass dominated swamp in 2011 (NigatuWondrade *et al.*, 2014).

High chemical and alkaline levels have recently been found in Ethiopian waterways such as Tikur Wuha River and Hawassa Lake near the Hawassa textile industry. This has resulted in a rise in temperature and pH levels and threatening the local environment Wastewater is being released directly into drains that connect the industry to the main drainage network and to the Tikur Wuha, which flows into Lake Hawassa. These practices cause a real threat to the environment in general and the aquatic habitat in particular. As a result, a rise in temperature could negatively affect fish migration and ultimately the species reproduction. The pH level

recorded suggests that Hawassa textile effluents have high levels of alkaline, which could be due to dyeing and printing processes in the nearby textile facilities. In general, the textile industry discharges a wide variety of pollutants from all stages in the processing of fibers and fabrics. These include liquid effluent, solid waste, hazardous waste, emissions to air and noise pollution (Lainie, 2015). At existing production capacity it discharges $50m^3$ of waste water per hour, raising to $120m^3$ at full capacity. The effluent is coloured, has bad odour, high in BOD and total suspended solid. About $1,200m^3$ of waste water is discharged daily. The factory has chemical waste treatment facilities (alkaline and acidic dosage unit) but none of these are functional, it is said, of the prohibitive cost of hydrochloric acid and sodium hydroxide).). There is a lack of scientific information on the type, magnitude and velocity of ecological damage caused by this industrial effluent to these ecosystems (Zerihun Desta ,2003 and Birenesh Abay,2007)

Therefore, it is useful to investigate the abundance of *C. papyrus* in this landscape and understand it ecological roles with regard to trapping pollutants. Moreover the ethnobotanical uses of wetland vegetation around Tikur Wuha are never documented earlier thus need prior attention so as to run targeted conservation activity in the area.

1.2 Objectives

1.2.1 General objective

The general objective of this study is to investigate the status and ecosystem functions of *Cyperus papyrus* in Wetland of (Tikur Wuha) Southern Ethiopia, and to study its local ethnobotanical uses.

1.2.2. Specific objectives

- To assess the current population status of *Cyperus papyrus* in Cheleleka wetland, Southern Ethiopia.
- To identify the role of *Cyperus papyrus* in terms of water purification by investigating the physico-chemical properties of Bishaan Gurraachaa (Tikur Wuha).
- To determine ethnobotanical uses of *Cyperus papyrus* in the study area and
- To identify the environmental and human factors influencing the population distribution and density of *Cyperus papyrus* in the study area.

1.3 Research questions

The following research questions were formulated in order to achieve the above objectives:-

- What are the factors that determine the population status of *Cyperus papyrus* in the study area?
- Does *Cyperus papyrus* play a role in water purification in the Cheleleka wetland? To what extent and how this ecological function of this plant is affected by the anthropogenic factors in the area?
- What are the ethnobotanical uses of *Cyperus papyrus* in the study area? How do the local community utilize this resource and what is the level of awareness among the local community on anthropogenic threats on this species?

CHAPTER TWO

2.Literature review

2.1 Taxonomy of *Cyperus papyrus*

Cyperus papyrus is known by various vernacular names such as dengel (Amharic), alaaduu (Oromifa), paper-reed, papyrus (English), Egyptian paper plant, Egyptian papyrus plant, Nile grass, paper plant, , papyrus plant, bull rushes, bulrush and papyrus sedge. Synonyms of *Cyperus papyrus* are *Chlorocyperus papyrus* Rikli, *Cyperus domesticus* Poir.;*Cyperus papyraceus* Crantz; *Cyperus papyrus* L. ssp. *antiquorum* (Willd.) Chiov.;*Cyperus syriacus* Parl and *Papyrus antiquorum* Willd (Beentje, 2017).

2.2 Description of *Cyperus papyrus*

Cyperus papyrus is a plant which is large, robust perennial with a stout creeping rhizome. Rhizome 3-6cm thick, central part of white air tissue surrounded by a light brown harder outer cylinder: on the outside densely covered by black scales, 5-10X5-10cm. culm 200-500x0.2-4cm(0.2-1.5cm thick immediately below the inflorescence), 3- angled with rounded angles, green. Leaf-blades absent: sheath black or red brown, innermost almost woody, 30-45x0.2-0.5cm below, the lowest much shorter. Inflorescence a compound umbel like anthela 30-60x30-80cm. Major involucral bracts 5-10x1-3cm, light brown, never green. Major peduncles 200-600 per culm, 5-40x0.1-0.15cm. Each inflorescence branch with a simple umbel of 2-5 spikes: major secondary bracts filiform 4-12x 0.05-0.15cm, green. Spikes 15-30x8-12mm, with 12-40 spreading spikelets. Spikes sessile or on up to 2 cm long peduncles. Spiklets 3-5x0.7-1mm, cylindrical to slightly compressed. Glumes 2-2.25 mm long, ovate, light-brown (rarely dark brown) to golden with green midrib ending below the obtuse apex. Style with 3 long branches. Nutlet 0.9-1.1x0.4-0.5mm, ovate, 3-angled, grey with almost smooth surface (Sue. *et al.*, 1997). *Cyperus papyrus* is a large, emergent, aquatic perennial may grow to more than 5 m high, making it one of the largest sedges in the world. The culms can be so dense and impossible to penetrate by human that the species is an ideal candidate for biofencing. The most conspicuous features of *Cyperus papyrus* is the bright, green, smooth, bladeless flowering culm and the "featherduster" flowering head (Levitin*et al.*, 2003).

It reproduces through both sexually by seed formation from the umbels and asexually by vegetative reproduction through the rhizome. Young floating papyrus mats can detach from the shoreline to be dispersed by wind and wave action; they then may join existing mature stands elsewhere or establish new populations along formerly unoccupied shorelines (Terer*et al*., 2012).

During development, the vegetative shoot grows out from the rhizome with the umbel fully enclosed in a sheath. The sheath surrounds the base of the culm in later growth stages. The developing papyrus goes through different growth stages starting as young elongating culms with closed umbels, then elongating culms with umbels just opening, fully elongated culms and fully expanded umbels, senescent culms (≤ 40% achlorophyllous) and finally dead culms (≥60% achlorophyllous).

Tropical wetlands are often unstable environments and in particular they are subject to substantial water level fluctuation. However, the loose structure of the floating papyrus rhizomes allows a free exchange of water and dissolved matter from underneath into the rhizome mat. The effect of these fluctuations in water level on the natural regeneration of papyrus is unknown, although natural regenerative capacity is known to be influenced by water depth (Alfonse *et al.,* 2014).

Papyrus has a high photosynthetic and productive potential due to the presence of C_4 photosynthesis, a characteristic shown by many high yielding tropical grasses. Under optimum conditions, in hydroponic culture, papyrus has been shown to have very high short-term rates (125 g dry weight m^{-2} day^{-1}) of primary production and under natural conditions rates of aerial primary production have been shown to be 6607 g m^{-2} y^{-1} (Francis *et al.,* 1997).

2.3 Distribution of *Cyperus papyrus*

In ancient Egypt, *Cyperus papyrus* has been used for paper-making, food, medicine, fibre and shelter for thousands of years. Egyptians and their trading partners may well have been responsible for introducing papyrus plants to the Middle East, southern Europe and other parts of Africa. Spread of the species to other continents North America and Australasia, for example came much later, as the result of people deliberately transporting plants or seeds for ornamental or potentially useful purposes.

Cyperus papyrus is distributed in tropical central Africa, at the upper parts of the White Nile, from where it penetrates westward into Lake Chad and the Niger region. It is cultivated in Egypt since the Ancient Empire and was introduced in some parts of the Mediterranean basin, and in America and Australia (Juffe, 2010).

It is quite common throughout Africa and can occur in very dense populations. The countries those contain native *C. papyrus* are Angola; Botswana; Burundi; Chad; Congo; Congo, Côte d'Ivoire; Egypt; Ethiopia; Gabon; Guinea; Kenya; Liberia; Malawi; Mauritania; Mozambique; Namibia; Rwanda; South Africa; Sudan; Tanzania, United Republic of; Uganda; Zambia and it is introduced to Benin; Ghana; Mali; Niger; Nigeria; and Senegal (Juffe, 2010).

The introduced range of *C. papyrus* now includes countries throughout the world with tropical, subtropical or Mediterranean climates, including Spain and Italy (Sicily), the USA (where it has escaped from cultivation and become naturalized in California, Louisiana, Florida and Hawaii), South America and Australia (Queensland, New South Wales and Western Australia) (GBIF, 2015).

In Ethiopia, *Cyperus papyrus* is found in Nile river system, along the shore lines of the rift valley lakes such as Lake Ziway, Lake Hawassaalong the coast of Lake Tana and its surrounding wetlands (FAO, 1996).

2.4 Importance of *Cyperus papyrus*

Historically papyrus has been very important in the economics of the world. In ancient times papyrus was important in making paper that was used for many reasons; from books to government documents. They started to use it for writing on circa 5000 years ago, and carried on up until the 8th or 9th century, when fibre materials replaced it as the medium of choice for literary Egyptians.

It was also adopted by the Greeks and extensively used by the Roman Empire. The Greeks began using papyrus for writing material as far back as the fourth or fifth century B.C. Its use continued by the Romans and Greeks as recently as the fifth century A.D. The word paper is even derived from the Egyptian 'papyrus. Papyrus has also been used to make sandals, boxes, ropes, mats, cloth, and building materials. The reeds were also bundled to make boats; a scene from an ancient temple also depicts a boatman wearing a collar of papyrus as a life preserver. Old papyrus paper was also recycled into mummy wrappings. The pith and rhizomes were also boiled and eaten, and the rhizomes were dried and used for fuel

In modern times papyrus is not used as a paper product. *C. papyrus* has made a comeback on the Nile River recently due to fascination by tourists. Today the most important uses of papyrus are that of ecological resources. The rhizomes of the plant prevent soil erosion and trap polluted sediments. A study from 1997 showed that *C. papyrus* is useful in wastewater treatment. The study showed that papyrus reduced the amount of nitrogen and phosphorus in wastewater by more than fifty percent (Matt 2001).

2.5 Economic importance of *Cyperus papyrus*

In Ethiopia, *C. papyrus* is one of the important wetland resources which serve as sources of income for local communities (farming communities) and some urban dwellers. Large number of people living in the vicinity of papyrus depends on it for their livelihood. Rural inhabitants

near papyrus swamp in most parts of Ethiopia harvest papyrus for personal use or to produce goods to sell (AssefaTessema, *et al*., 2013).Papyrus is used as a raw material for making of different handicrafts, like sleeping mats, boats and household utensils. The flowering part of the plant is sold in towns to be used for floor covering during occasional ceremonies. It also used for livestock grazing. Farmers use it as the main grazing field. They use it for making boats, grazing their livestock, fire fuel, construction of their houses, sleeping mat and selling the flowering part to the nearby towns for floor covering during occasional ceremonies.

A variety of products and services of considerable benefits offered by papyrus, which include Habitat protection, nature conservation and livestock production, wildlife conservation Food for animals, energy, raw material used for craft making and ceremonial purposes, construction of houses, making boats (Tankwa) and making mattress.

(http://www.selamtamagazine.com/stories/papyrus-and-lake-tana). The plant is also used for a wide range of products.

I. *Cyperus papyrus* boat

Cyperus papyrus is very important to make boats. In the ancient time Egyptian men were the boat makers cut down and tied the papyrus stalks and carried them to a place where they could best construct them. The mature *Cyperus papyrus* is tightly bound together in to an oblong slim shape. A light portable boat is the result (Elaine 2008).

II. *Cyperus papyrus* in the house hold

Cyperus papyrus has many importance in order to make items for dwellings. Such as utensils and containers, boxes, crates and baskets to store goods like writing. Equipment. Among others things papyrus rope is used in webbing for beds, woven floor mats and matting for walls. Beside this it has a part to eaten. The starch / stalks is consume row, roasted and tested even after being baked/boiled. In addition to this dried papyrus was used for healing fistula and it was an aid to open all abscess for the application of medicine. Burnt *Cyperus papyrus* ash was a caustic remedy and cures alcer (Elaine 2008).

III. *Cyperus papyrus* for biofuels

Biofuels are an important form of green energy and Papyrus has been considered as a potentially important source of biofuel in some African countries, because of its high productivity and its convenient habit of growing in large, relatively pure species stands (Peter 2013).

IV. *Cyperus papyrus* for traditional ceremony

The head of papyrus plant is used for floor cover during traditional and coffee ceremony in Ethiopia.It is the major source of income for low income people of the local community. They collect the leaf from the top part of the papyrus plant and sold it in the nearby town (AbyeKindie, 2001).

2.6 Ecological importance of *Cyperus papyrus*

I. Cyperus papyrus for water filtration

Papyrus swamps are known to have the ability to trap sediments, and therefore are useful for filtering out pollutants including heavy metals. Several analyses of heavy metals Cd, Cr, Cu, Pb, and Zn contained in the plant have shown that C. *papyrus* plays an important role in metal retention, particularly in its rhizomes. C. *papyrus* is effective in filtering the sewage discharged, resulting in purified water. C.*papyrus* swamps are efficient in nutrient (nitrogen and phosphorous) removal and might be suitable for the purpose of cleaning domestic waste water. (Peter 2013).

C. papyrus can be efficient indicators of water quality and their presence may enhance water quality due to their ability to absorb excessive loads of nutrients and heavy metals (US EPA, 2002).

The root structures of papyrus provide more microbial attachment sites, sufficient wastewater residence time, trapping and settlement of suspended particles, surface area for pollutant adsorption, uptake, assimilation in plant tissues and oxygen for organic and inorganic matter oxidation in the rhizosphere, accounting for its high treatment (pollutant removal) efficiency (Lim, 2016).

The papyrus plants that grow in wetlands take up and store nutrients and heavy metals from the soil and water(Muthuri, *et al*., 1988;YezbieKassa and SeyoumMengistou, 2014). These nutrients are either released back into the environment when plants die or are removed when plants are harvested perhaps for food or building materials. Dissolved nutrients, such as nitrates and phosphates from fertilizers and sewage effluent are taken up by wetland papyrus plants and stored in their leaves, stems and roots, so helping to improve water quality. The astonishing productivity of papyrus plants makes them particularly good for removing excess nutrients from water (Lim, 2016).

According to Muthuri, *et al*. (1988), the nutrient uptake rate of *C. papyrus* is 7.10 kg/ha/day and 0.24 kg ha/day of nitrogen and phosphorus respectively. Numerous studies (Abe *et al*., 1997; Fonkou,et *al*., 2005; Odinga, et al., 2011;YezbieKassa and Seyoum Mengistou 2014)

have carried out on the pollution removal efficiency of *C. papyrus* and they all have reported that, the plant has high potential to remove pollutants such as nutrients and heavy metals.

II. Cyperus papyrus for the protection of soil erosion

C. *papyrus* protect shorelines from erosion due to wave action or currents. The submerged parts of large papyrus wetlands can be very extensive and their roots are spread over the shore of water body and form floating mat. This creates a physical barrier to waves travelling across the surface of the water and helps to prevent soil erosion and trap polluted sediments in the wastewater. Papyrus can therefore protect the shoreline of the water bodies from being eroded, particularly during storms.

III. Cyperus Papyrus for carbon sequestration potential

As stated by Jones and Humphries (2002),papyrus plant possesses the remarkable ability to sequester and assimilate carbon through photosynthesis and to lock carbon in the shoot and root system like other plants. According to (Saunders, *et al*., 2014), 88 t C ha^{-1} is stored in the aboveground and belowground components of papyrus vegetation. Through their inherent ability to take up large amounts of CO_2 (1.6 kg C m^{-2} y^{-1}) and convert it into oxygen, papyrus plant can help regulate CO_2 emissions that contribute to global warming.The CO_2 absorbed by the papyrus does not release back into the ecosystem as it is retained by the plant, and after harvesting, the culms and leaves are used for different purposes. Thus, papyrus and other macrophytes serve as a carbon sink and the resulting environmental benefits are immense. Papyrus thus serves as an important niche for carbon conversion and locking and hence, regarded as an important contribution to mitigating climate change

IV. Cyperus papyrus providing Habitat for Aquatic Life

Papyrus and other aquatic vegetation provide important living and breeding substrate for small animals such as aquatic insects, snails and crustaceans which intern supply food for fish and waterfowl (zurHeide, 2012). Studies have shown that papyrus vegetated areas support more of these creatures than do unvegetated areas. The complex habitat beneath papyrus wetlands also provides ideal breeding, nesting, feeding and escaping ground for fish, amphibians and waterfowl. Studies have shown greater catches of fish can be made in papyrus swamps compared to the open water of the lake; one of the reasons for this is the availability of food for fish that is found on the roots of the plant. Fish also take refuge from birds that eat them by be neat papyrus, which helps to increase the overall size of the fishery (https://www.imarisha.le.ac.uk/current-research-summaries/benefits-and-values-papyrus).

In the shore of Lake Tana, papyrus has also been identified as a valuable spawning and breeding ground for a large variety of fish species and resting and feeding sites for different threatened and migratory bird species (ZurHeide, 2012).

V. *Cyperus papyrus* for the Base of Food Web

In most aquatic ecosystems, aquatic plants (hydrophytes) are important components of food web dynamics. Much of the food is derived from plants. The majority of aquatic plants are consumed only after they have died and partially decomposed into detritus. Detritus is eaten primarily by aquatic insects, invertebrates and larger crustaceans (Rejmánková, 2011). These detritivores are in turn consumed by fish. Lastly, the fish are consumed by the top predator such as sharks (Rejmankova, 2011).

2.7 IUCN Assessment information of *Cyperus papyrus*

Cyperus papyrus is widespread and while it is possibly declining in parts of its range due to draining of swamps for agricultural use it is not thought that global population decline is likely to qualify for a classification within a threatened category. The category is least concern (LC) (http//dx dol. Org/10.2305/IUCN.UK 20171. RLTS. T164158A66891399. en).

2.8 Causes of *Cyperus papyrus* Degradation and Loss in Ethiopia

Eventhough, papyrus has played a great role in the socio-economic and environmental aspects, it has been degraded and lost by anthropogenic activities like other forest ecosystem (AyalewWondie, 2010). Rapid human population growth around papyrus areas with concomitant increase in the demands for papyrus land for other land use activities such as: agriculture, grazing, settlements and other developmental activates are the major causes of papyrus degradation in Ethiopia (LegesseTaffa, 2005). Furthermore, over exploitation of papyrus plants for different purposes such as construction of traditional houses, making reed boats, to make mattress, fire wood, rope and basket by the poor local communities are also the factors that account for papyrus reduction (Legesse Taffa, 2005;Ayalew Wondie, 2010; AssefaTessema *et al*. 2013).

Land use activities around papyrus swamps of Ethiopia are dominated by cultivation, livestock grazing and settlements (AssefaTessema *et al*., 2013). These activities have intensified in recent years and are of particular concern as they have led to other forms of disturbance to papyrus swamps such as pollution, burning and papyrus harvesting (Abye Kindie, 2001). As a

result of these and other factors the extent of papyrus in Ethiopia is highly reduced and found in the pocket areas of wetlands in which human beings cannot rich.

According to (Legesse Taffa, 2005), large extents of papyrus wetlands are drained to expand farmlands by local communities. In addition, papyrus vegetation in many places has been destroyed by deliberate fire outbreaks to use the land for cultivation. For example, more than 10 hectares of papyrus vegetation has been destroyed in Zanzelima Kebele at a place called Debre Mariam. It is easily recognizable that fire outbreaks not only destroy the vegetation but also the fertile soil and animals of the wetlands. Furthermore, papyrus plants are overgrazed by large number of livestock during the dry season.

Poverty, lack of strict law and lack of awareness are contributing factors for such papyrus and other ecosystems degradation in Ethiopia (Ayalewwondies, 2010). Despite being important and highly productive habitats, no Ethiopian papyrus swamp is formally protected and their area changes due to human encroachment over the years are unknown. These factors appear to be the major challenges in papyrus conservation in Ethiopia.

2.9 Policy concerning wetlands

International policies concerning wetlands include the Convention on Biological Diversity (CBD) (United Nations Environment Programme, 1992) and the Ramsar Convention (www.ramsar.org). Ethiopia has signed the former but not the latter. At the national level, two policies are important: The Conservation Strategy of Ethiopia (CSE), and the Water Resources Policy. Both concern wetlands directly, but the former focuses on ecosystem functions and biodiversity whilst the latter concentrates on hydrological functions. Non wetland policies with an impact on wetlands include national government policy on food security, policy on production of cash crops, especially coffee, and the resettlement policy which moved groups of people hit by drought 6 and famine to regions in the south and west of Ethiopia. The effect of all these policies has been an increase in the use of wetlands for agriculture due to a shortage of land.

Most communities in wetland areas in Ethiopia have local policies concerning the wetlands, often in the form of ‘unwritten’ rules based on tradition and the fact that the wetlands are usually in common ownership. These rules must be taken into account by policy makers at higher levels (Rebecca, 2006).

2.10 Threats to wetlands

There is increasing pressure on African wetlands as the human population continues to grow, and more land for agriculture and development are needed. The threats posed to wetlands by this development are therefore becoming increasingly acute, and the rate of wetland loss is increasing. Some of the main threats to wetlands are outlined below. Physical alteration of the hydrology of the drainage basin of a wetland will affect the input of water to a wetland and/or its outflow. The construction of dams above or below a wetland will either reduce or increase the water flow to such an extent that the wetland is permanently damaged. Artificial stabilisation of water levels by damming would also harm a wetland since the rise and fall of the water level drives nutrient cycling.

Drainage of a wetland or unsustainable extraction of groundwater in the area will dry it out and may cause permanent damage, and will impair a wetland's ability to control flooding, since the soil has a reduced capacity to reabsorb water (Rebecca, 2006).
One of the main threats to wetlands, especially ones in or close to urban settlements, is development. A wetland can be completely removed by filling in and building over the wetland area, or development and industry nearby may impact on the water table so much that the wetland dries out. Mining is one such activity that will disturb the water table and destroy wetland areas (YilmaAbebe, 2003).

Another serious threat to wetlands from industry and development is pollution. As yet there is little control on industrial emissions in developing countries. Pollution from heavy industry, in the form of heavy metals and chemicals, will usually exceed a wetland's capacity to filter out such pollutants and can do serious damage to life in the wetland and make the 4 water unfit for use by communities in the area. Sewage pollution will also become a problem if the input of sewage exceeds a wetland's capacity to filter it, and such pollution will quickly lead to eutrophication of any open water; alter the species structure of the vegetation and make the water unfit for use.

Overexploitation of any wetland resources mentioned above, such as over- gathering reeds for thatching, will lead to an imbalance in the wetland ecosystem and may change its structure and species composition permanently. The complete drainage of wetlands for agriculture has lead to a number of ecological and economic problems. These include a scarcity of thatching reeds, change in the vegetation composition, lowered water tables and an accompanying reduction in accessible water.

Other problems that develop over time include a decline in agricultural productivity in the cultivated wetlands which may eventually lead to reduced overall availability of land for crop production. In the same way as continuous cultivation of crops around a wetland will dry it out, afforestation of land upstream of a wetland may reduce the amount of water in lower reaches of the catchment, leading to a lowering of the water table and wetland drying.

Not all threats to wetlands are anthropogenic. Natural processes such as flood and drought may pose a threat to wetlands but the damage is not usually permanent unless the effects are exacerbated by other factors such as damming, irrigation and drainage systems. Erosion of substrates upstream and/or the wetland itself is also a natural process, but again any damage to the wetland will be greater if the hydrological system is greatly altered by man. The high productivity of wetlands can sometimes spell their own demise, albeit very slowly, by the process of succession. The build-up of biomass in the wetland can sometimes be so great that the water balance is altered, and the wetland dries out as open swamp vegetation is replaced by shrubs, and eventually, woodland. This natural process is greatly speeded up by wetland drainage and by the increase of sediment and nutrient input from upstream (Rebecca, 2006).

2.11 Wetlands in Ethiopia

In Ethiopia, wetlands cover nearly 2% of the total land area of the country. They are one of the most productive ecosystems and perform many functions that maintain ecological integrity. They provide lots of goods and services that encompass agricultural production, tourism, and biodiversity conservation, social, economic as well as cultural activities. More specifically, wetlands are crucial resources of income generation and livelihood for local communities. Major types of wetlands in Ethiopia are:- Freshwater wetlands, Saline wetlands , Marshland wetlands and Seasonally inundated wetlands (Tadesse Amsalu and Solomon Adisu, 2014).

CHAPTER THREE

3. Methods and materials

3.1 Description of the study area

This study was conducted in the Tikur Wuha wetland. Bishaan Gurraachaa town is located in the Oromia National Regional State in West Arsi Zone at the northern edge of Hawassa Lake. The town is situated at a distance of 266 Km south of Addis Ababa and 16 km south of Shashemene town and 4 km north of Hawassa city. It is found along the international road, which connects Addis Ababa with Nairobi, Kenya. The total area of the study area is about 34km^2 .The elevation ranges from 1692 to 1742 m a.s.l (above sea level). The wetland gets its name which is (Tikur wuha or black water) from the black humus rich soil bed. It serves different purposes for people, domestic use and wild life and which is also the only influent of Lake Hawassa. According to local population census conducted by Shashemene District Health Office in 2007, there were 1830 households, with about a total of 9151 inhabitants in Tikur Wuha town. The inhabitants of this town are government employees, merchants, daily labourers and farmers (Habtamu Mitiku *et al*., 2010).

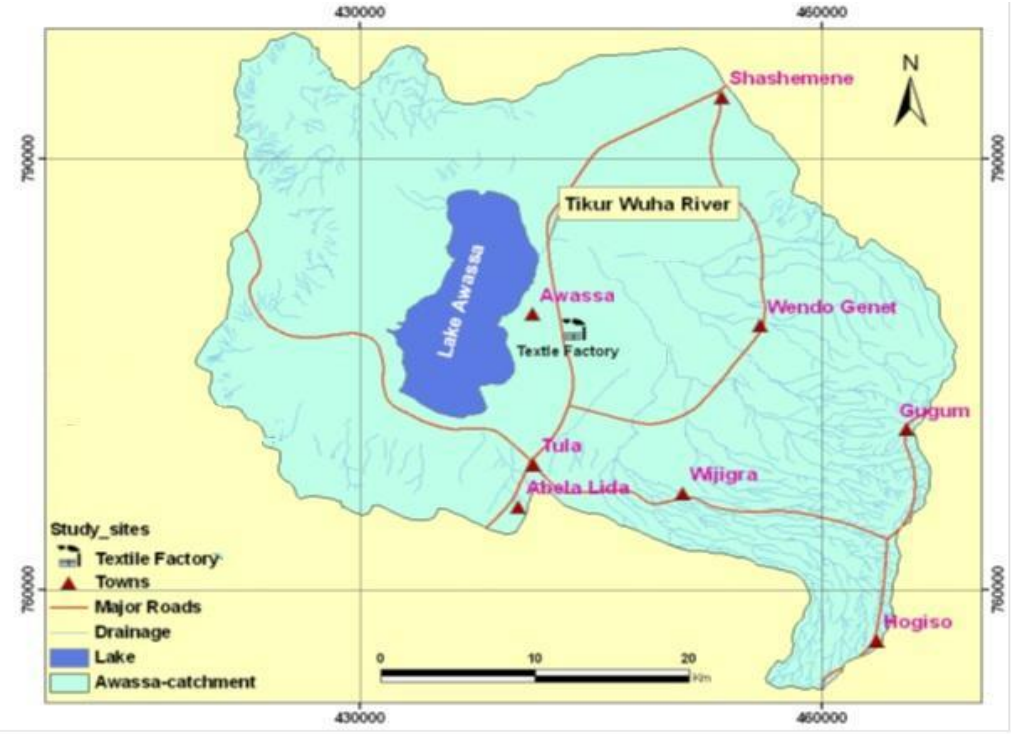

Figure 1. Map showing study location along Tikur Wuha River until it joins Lake Hawassa.

3.2 Climate

The climate of the study area is bimodal based on the 1997 – 2017 climate data from NMSA. January – February and mid-November to December are the periods with pronounced dry season. The mean temperature is over 20 °C and rainfall is over 970 mm.

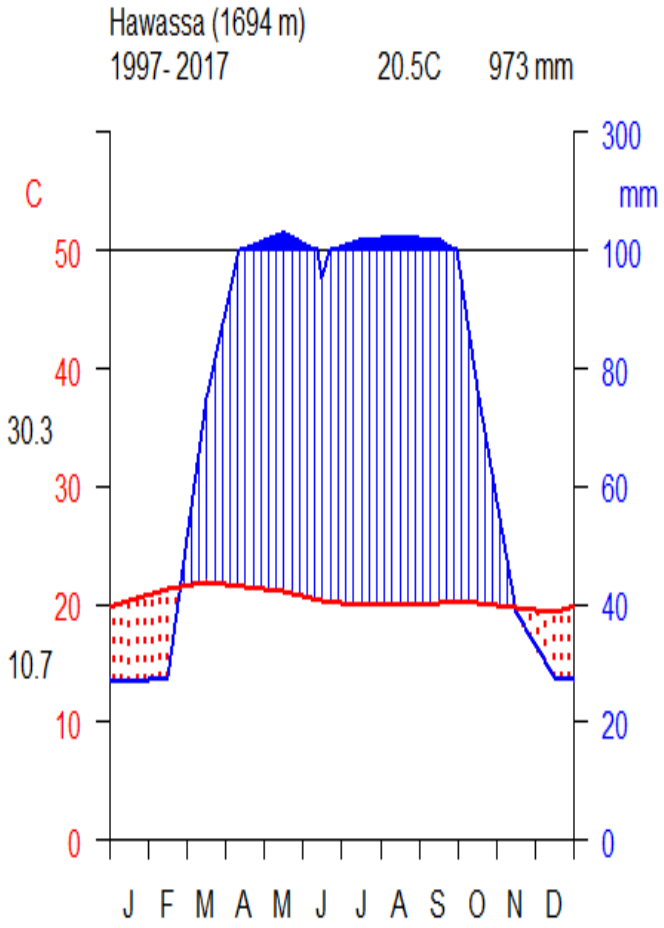

Figure 2. Mean monthly minimum, maximum and average temperature and rainfall in Hawassa (1997-2017).

3.3 Demographic structure of Bishaan Gurraachaa (Tikur Wuha) city

According to the projection of population and housing census in Tikur Wuha the age structure of the town is characterized by much higher proportion of young ages (36.1%) which is under 15 years old while the working age group accounts for 61.4% of the total population. Based on this data the Tikur Wuha municipal office report shows that there is high fertility and low

mortality (rapid population growth rate).On the other hand, the sex structure of the city which is the proportion of Male and Female population in the sex ratio of the city is about 1:1.08 which means Female population are slightly above than Male population number.

3.4 Vegetation and wild life in (Tikur Wuha)

Historically, the area was covered by dense forest. However, through time the forest resources have been declined. In this area patch of riverine forests are found along Bishaan Gurraachaa River in the south eastern part of the town. There are also some exotic tree species like eucalyptus tree throughout the town and its suburbs. In Bishaan Gurraachaa town there are major natural and man-made forests protected by the government, communities, cooperatives or any other organizations. Major types of natural vegetation ain the area include (forest, woodland, riverine, shrub & bush land, and savannah).

Varieties of wild life exist in Tikur Wuha town. Hawassa Lake is a home of different species of birds and mammals.

Lake Hawassa is one of the important bird areas in Ethiopia. It is a sanctuary for Palearctic migrant birds during the northern winter season. The birds that are found in and around the lake include: white breasted cormorant, white face whistling duck, spur-winged goose, red Knobbed coot, pygmy goose. The endemic yellow fronted parrot, Abyssinian black-headed oriel and black winged love bird are prominent around the lake area. Few mammals exist around the lake and vicinity. The species living around the lake are Hippopotamus, vervet, and Colobus Monkey and Anubis Baboon(EWNHS, 1996).

3.5 Drainage of Bishaan Gurraachaa (Tikur Wuha) town

Tikur Wuha town is situated at the centre of the Great East African Rift Valley which is widely associated with “major danger” seismic zone, hot and humid flat land. The majority of the town Rivers that originated from the East highland areas**.** Bishaan Gurraachaa wetland is a major river found in and around the town. On the other hand, most of the proposed expansion areas are characterized by gentle slopes toward the Hawassa Lake, but with a plateau along the north central part of the areas. The elevation of the land generally drops to the east, south and southwest direction facilitating the discharge of flood that finally ends up either into the Bishaan Gurraachaa River or the Hawassa Lake. Except fewer scattered plateaus to the west central part, the area is categorized as a flatland surface. Kelaleme and Chebi hills are also found surrounding the Lake of Hawassa in the area (NUPI, 1994).

3.6 Flow and source of Bishaan Gurraachaa (Tikur wuha) wetland

Tikur Wuha is the only perennial river which flows to the lake Hawassa. Tikur Wuha starts from Lake Cheleleka and it receives inflow from Wedesa, Gomesho, WeteraWendo, Shenkora, Werka, Wesha and Lango River which originate from the eastern ridge (YacobEsayas, 2010).

3.7 Soil classification in Tikur Wuha town

According to the soil data which is reported by Water Work Design and Supervision Enterprise (WWDSE, 2000), Tikur Wuha town has different soil types. The classification is depends on the physical and chemical characteristics including depth, colour, texture, pH and other.

The soil type found in Tikur wuha area are Andosols, Cambisols, Vertisols, Levisols and other. Soil has its own chemical and physical characteristics those are very important in describing and differentiating among them. The most useful characters include: - effective soil depth, soil colour, acidity or alkalinity, texture, electrical conductivity and base saturation.

Soil colour in Bishaan Gurraachaa vary from very dark brown to pale brown. The soils of irrigable areas of Tikur Wuha have fine to medium textures. The soil structure of Tikur Wuha town are strong to week, fine to coarse and dominantly sub angular blocky.Soil reaction in Bishaan Gurraachaa is moderately acidic to very alkaline, the ph is found between 5.8 and 9.8.

3.8 Land use and land cover in Tikur Wuha

Land use is one of the most needed factors that affect evapotranspiration, runoff and surface erosion in a watershed. In 2004 recorded data, Land uses of Tikur Wuha is changed and dominated by range brush, range grass pasture and wetland mixed. This all indicated that the lake is already going to be swampy (WWDSE 2000).

3.9 Agriculture in Bishaan Gurraachaa

In Bishaan Gurraachaa the farmers practiced agricultural activities which are very important for the consumption and transfer to central market especially to Hawassa and Shashemene even to abroad the country. Maize, Boloke, Teff, Wheat are major crops of the area. There is also agricultural activity based on cattle fattening.

3.10. Tourism and tourist attraction centers in Bishaan Gurraachaa

Tourism is smokeless industry which nocks the hearts of tourists and recreates the mind of every individual. This phenomenon includes tangible and intangible which can inspire the emotion of tourists mind. Currently existing tourist attraction sites are found in the town such as Lake Hawassa which contain a lot of beautiful birds like Anatidae and other mammals such as hippopotamus.

Cabbi and Kalalame mountains, the place where Oromo Pastoralist live around here, even the names comes from this event which means these people feed their livestock the grass called Kalala. This grass found at the tip of the mountain, then they called the mountain Kalalame. Haitu (hot spring), it is said to be considered as a source or origin of Bishaan Gurraachaa River. Eventhough it is not scientifically proved and as mentioned by the elderly people of the area, this hot spring helps for traditional healing for different diseases.

3.1.1 Data collection

3.1.2 Reconnaissance survey

A reconnaissance survey of the study area was conducted on November 2017, to obtain preliminary information such as vegetation pattern and to decide on the number of sample plots and to identify sampling design accessibility and to identify sampling design. The reconnaissance survey was conducted with the help of the local guide and staff members of developmental agents to obtain ideal and proper information.

3.1.3 *Cyperus papyrus* population status data collection

In order to study the population status of *Cyperus papyrus*, data were collected by using line transect survey. A total of two transect lines were used and the *Cyperus papyrus* plant species was counted from 40 quadrats of (5mx5m=25m^2 for mature individuals) and (1mX1m=1m^2 for young shoots) laid on the right and left side of the wetland following Kent and Coker (1992). The distance between successive sample plots along the transect line was about 100m. The first transect line was started purposively from the place which contain high population density of *Cyperus papyrus.*

3.1.4 Ethnobotanical data collection

To undertake the socio economic survey, a total of 100 households were selected purposively (age and gender based) and interviewed using semi-structured questionnaire.

The sample size for qualitative data was determined using Cochran's 1997 formula, which is

$$n = \frac{N}{1+N(e2)}$$

Where n=sample size for the research, N=total number of households in Tikur wuha town.
e= maximum variability or margin of error 5% (0.05).

Two focus group discussions were also made with representatives of church administration, development agents, Kebele administration, Woreda administration, local people, and youth representatives using open-ended questionnaire. Number of participants in group discussion were 15 for each group.

The informants were selected between the ages of 18-80 and 60 Men (60%) and 40 Women (40%) participated in the interview. The interviews and discussions were conducted in the official language of the region Afaan Oromo with the help of translator and a few in Amharic languages. Local guides were hired and trained to properly administer semi-structured interviews and also served as local translators. Interviews with semi-structured questionnaires were administered to get more information on the utilization of *Cyperus papyrus*, current harvesting, sustainability and perception on regeneration and management practices by the local people.

Special emphasis were placed on the utilization of *Cyperus papyrus* plant and more observations are focused on the changes of its coverage over time. Focus group discussion (FGD) was used in order to get good information in depth knowledge and verification of information which was not documented earlier. In addition to this FGD was very important in identifying and understanding the existing traditional history and emerging local practices in relation to the use of *Cyperus papyrus*. Both interviews and focus group discussion were conducted in a place where the informants were most comfortable.

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Figure 3. Interview with elders. [Photo courtesy by Hiwot Fiseha, 20/06/ 2010]

Figure 4. Interview with fishermen in Tikur Wuha wetland. [Photo courtesy by Hiwot Fiseha, 22/06/ 2010]

3.1.5 Market survey

Market survey was undertaken to record *Cyperus papyrus* landraces that are sold in the market together with information on their market values. Therefore, local markets in the study area and neighbour town were visited and semi-structured interview and questionnaire were used. During this study two different markets were selected purposively (Tikur Wuha Gebeya and Hawassa Tileku Gebeya) and one seller of each shop was selected randomly in order to record its market prices and related data. Totally 40 informants (20 for each market) were interviewed in the market.

Figure 5.Market survey interview with mattress seller. [Photo courtesy by Hiwot Fiseha, 25/06/2010]

Figure 6. Mattress products in Tikur Wuha town. [Photo courtesy by Hiwot Fiseha, 25/06/ 2010].

3.1.6 Physico –chemical data collection

The sampling sites were chosen to evaluate the role of *Cyperus papyrus* plant on the purification of water (Tikur Wuha wetland) and to estimate the quality of water with in the wetland system. Four monitoring sites were selected. The sampling sites were designated as S1 to S4. The samples were collected directly from Tikur Wuha River during the study period.The sites were at the entrance of the lake, the lake exit, areas with high density of *Cyperus papyrus* populations and few or no *Cyperus papyrus* populated area.

From each sampling site, triplicate water samples were collected in one litre acid washed polyethylene bottles, prior to sampling each bottle was washed with diluted acid and double distilled water and before actual sampling these bottles were rinsed with waste water to be sampled. Samples were transported to Addis Ababa University Eco physiology laboratory. Samples for heavy metal analysis were fixed by adding 2-3 drops of Nitric acid. The samples were labelled carefully and then placed in 4^0c. The bottle of water samples were kept in the ice box during transportation prior to the laboratory activity. The ` samples were then analysed for different parameters such as determined (temperature, conductivity, turbidity, pH, dissolved oxygen), total nitrogen, total phosphorous, total Mercury, total Arsenic, total Cadmium and total Lead.

Turbidity, temperature, pH, conductivity, dissolved oxygen were measured with a combined portable Turbidity, Temperature, pH, Conductivity, Temperature, Dissolved oxygen meter (YSI model 58) (NegashAtnafu et al., 2011).

Total Nitrogen (TN) was tested through APHA 4500-Norg C. Semi- Micro Kjeldhal Method, Total Phosphorous (TP) was tested in APHA 4500-PE. Per sulphate digestion _ Ascorbic acid colorimetric, Mercury (Hg) was tested in APHA 3111C. AAS, cold vapour technique, Arsenic

(As) was tested in APHA 3112B. Cold Vapour Atomic Absorption Spectrometry Method, Cadmium (Cd) was tested in APHA 3111C. Air- acetylene Flame Method and Lead (Pb) was tested in APHA 3111C Air- Acetylene Flame Method.

During the sampling periods, the water was highly turbid, with brown colour and bad (unpleasant) odour. The bottom substrate was dominated with mud and which was also visible in the outside part of the water. The people in the surrounding area used the water for washing their clothes, drinking, preparation of food, washing dishes, for animal drinking, irrigating vegetables and bathing. The water volume decreased since it was taken for construction purpose in an amount of around 90,000 litres of water with in a day.

Figure 7. Physico-chemical data collection at Tikur Wuha w0etland.[Photo courtesy by Hiwot Fiseha, 28/06/ 2010].

Figure 8. Sedimentation in Tikur Wuha wetland. [Photo courtesy by Hiwot Fiseha, 28/06/ 2010].

Figure 9. Up taking of water from the river for road construction purposes. [Photo courtesy by Hiwot Fiseha, 28/06/ 2010].

Figure 10. People use the water for drinking purposes. [Photo courtesy by Hiwot Fiseha, 28/06/ 2010].

3.1.7 Direct field observation

Field observation by the researcher was handy in gathering the data on utilization of the *Cyperus papyrus* and activities taking place in the Wetland. The researcher made observations on farming, recreation sites, uncontrolled grazing and harvesting, fishing with traditional methods activities around the wetland and also market activities in Tikur Wuha and Hawassa town. Personal interview and focus group discussion data were recorded and transcribed

CHAPTER FOUR

4. Results

4.1 Population density of *Cyperus papyrus* in Tikur Wuha wetland.

Cyperus papyrus in the study area (Tikur Wuha) has its own local name which is "Fila" or "Ketema" and the local people use it for different purposes. Figure 11, presents the number of mature and young individuals of *C. papyrus*. There are more mature plants than young. In some cases, there are only either mature or young plant but not both. Furthermore, the number of mature plants was more than that of young ones. Noteworthy is also that sites with either mature or young are missing show a declining trend in terms of the number of individuals.

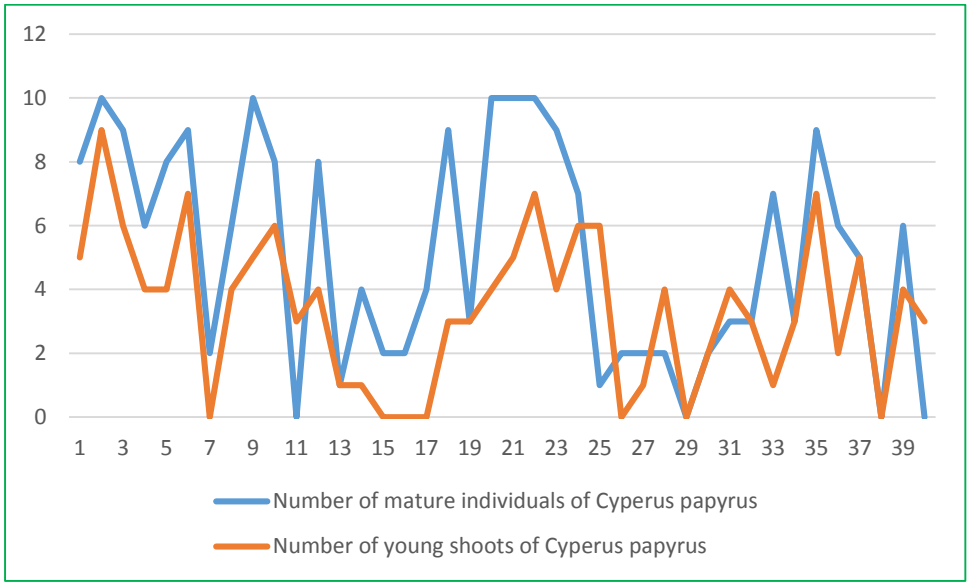

Fig.11. Mature versus young plants of *C. papyrus*

4.2. Physico-chemical properties of water

The physico-chemical analysis has focused on three major sampling approaches to assess the roles of *C. papyrus* in terms of filtering pollutants. These are HC (areas with high *C. papyrus* pollutions), LC (areas with low *C. papyrus* pollutions) and WO (with no *C. papyrus*). From the evaluated chemicals contents of sampled water in the laboratory chemicals such as Cadmium (Cd), Lead (Pb) and Mercury (Hg) were not detected and reported at the time of laboratory test and the result is reported as ND (not detected or zero 0.

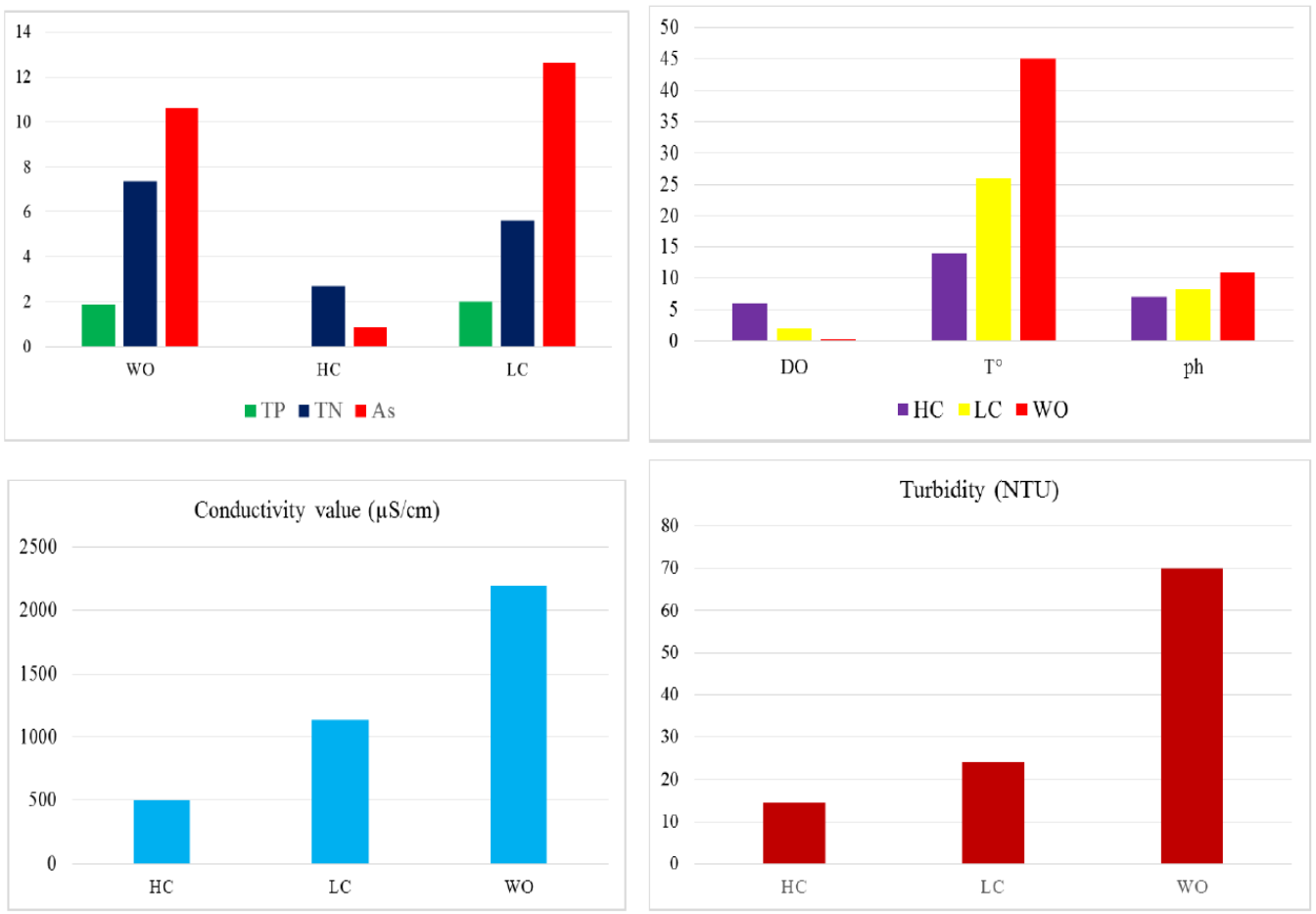

Figure12. Physico-chemical properties of sites with different levels of populations of *C. papyrus.* Key: TP- Total Phosphorous; TN- Total Nitrogen; As- Arsenic; DO- Dissolved Oxygen, T°- Temperature; WO- without *Cyperus papyrus*, HC- High *Cyperus papyrus*; LC- Low *Cyperus papyrus*.

The amount of total Nitrogen in sites with high *C. papyrus* was low and total phosphorus was lacking (Fig. 12). On the other hand, there is a contrasting trend of arsenic and total phosphorus between areas with low and no *C. papyrus* populations. The highest temperature was recorded for sites without this species. Although there is a relatively higher level of dissolved oxygen in sites with high populations, the pH is comparable in all three sites. Turbidity and electric conductivity have shown a similar trend, i.e., they have increased from HC through LC to WO.

4.3 Ethnobotanical studies

4.3.1 Uses of *Cyperus papyrus*

Cyperus papyrus plant in this area has a lot of benefits including cultural and economic values, such as medicinal, household material construction, boat making, mat making, house construction, for rituals (spiritual ceremonies), decoration in recreational sites, fire wood, fodder and also for fish trapping purposes but according to the local people in Tikur Wuha the plant is more applied for boat making, mat making and rituals.

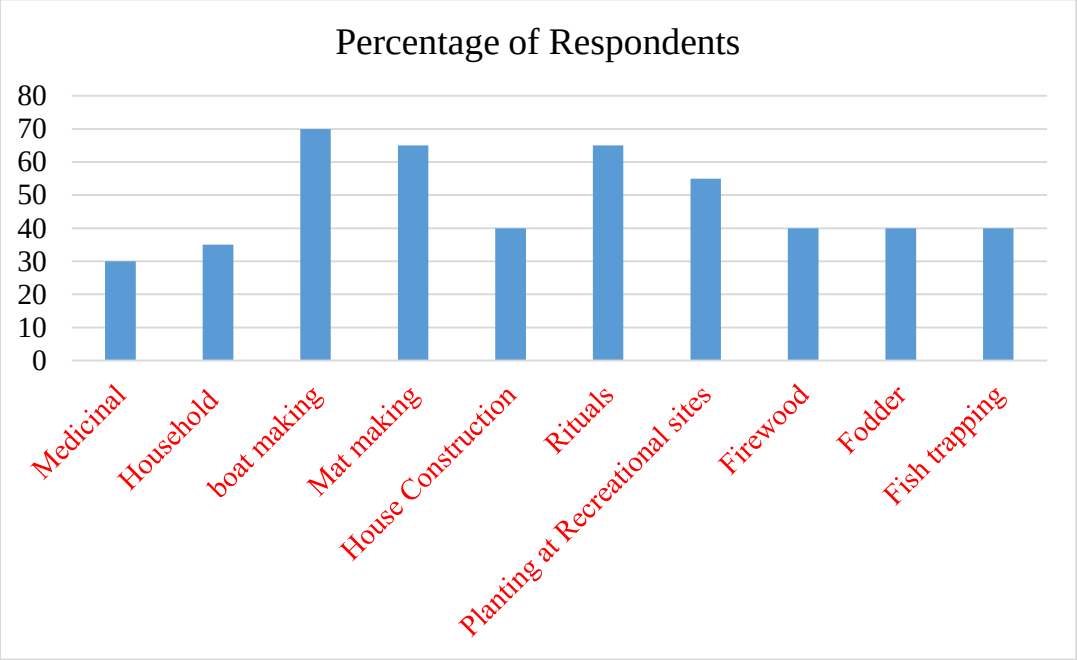

Figure 13. Economic value of C. *papyrus* based on the informant's response.

4.3.2 Part used of *Cyperus papyrus*

From the plant part of *Cyperus papyrus* stem (culm) is used by highest proportion of informants (80%) of the local people for different activities such as boat making, house construction, household material, mat making and other. The umbel or inflorescence part of the plant is very important for medicinal purposes through mixing with butter and the 30% of local people use it for a person burnt by boiled water or boiled oil in order to heal affected part of the skin. Without the umbel and culm part of the plant, the local people in Tikur Wuha do not use other parts of the plant like Scale leaves, Juvenile leaves, Roots and Rhizomes.

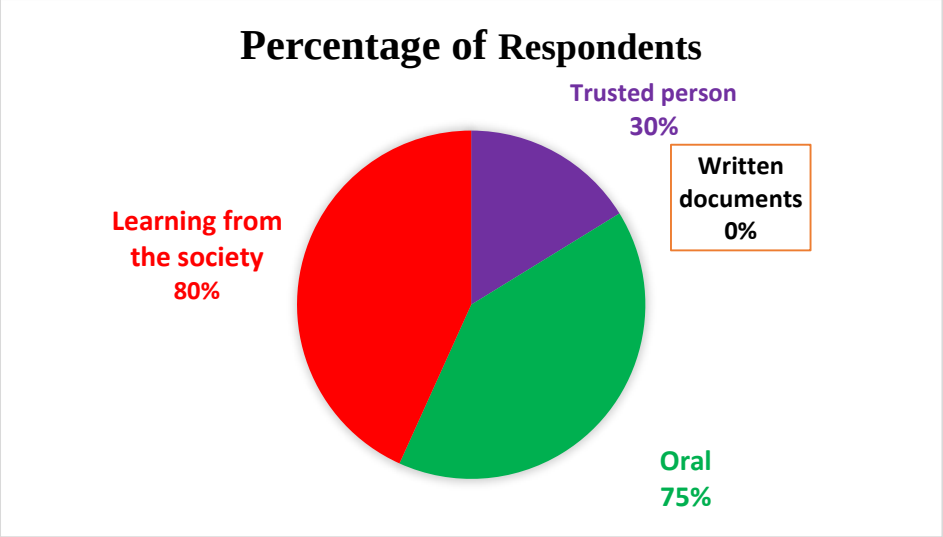

Figure 14. Traditional knowledge of Cyperus papyrus transfer techniques in Tikur Wuha.

4.3.3 Preference ranking

Ten use categories were evaluated to assess the uses of *C. papyrus* by the local communities (Table 2). Boat making was found to be the most cited used of this species by the respondents followed by mat making and rituals. Although some respondents attributed firewood usage to this species, this use category was one of the least cited by other informants.

Table 1. Preference ranking of the uses of *C. papyrus*. 1, more use; 0, no use

No	Uses of *Cyperus papyrus*	Respondents giving value for the use of *Cyperus papyrus*															Total score	Ranking
1	Medicinal	1	0	0	0	1	1	1	1	0	0	0	0	1	0	0	6	8th
2	House hold	0	1	0	1	1	0	1	0	1	0	1	1	0	1	1	9	5th
3	Making boat	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1st
4	Mat making	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	14	2nd
5	House construction	1	1	1	0	1	0	1	0	1	1	1	0	0	0	1	9	5th
6	Rituals	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	13	3rd
7	Fire wood	0	0	0	0	1	1	1	0	1	0	1	0	1	0	1	7	7th
8	Fish trapping	1	0	0	1	0	1	0	1	0	0	1	1	0	0	0	6	8th
9	Planting at recreational sites	1	0	0	1	0	0	1	1	1	1	0	1	0	0	1	8	6th
10	Fodder	1	1	1	1	1	0	0	1	0	1	0	1	1	1	1	11	4th

4.3.4 Market survey

Cyperus papyrus is widely used for different economic activities thus provides sources of income for the local communities. In the study area and neighbour town market, survey has revealed that the species is used for making mattress. More men was involved in mattress making than woman. The production source of this mattress is the wild *Cyperus papyrus* and the most commonly used part is the culm (stem). The current market status of mattress is already decreasing and most of the interviewed respondents believed that the populations of the species has deteriorated over years. Although the price of the mattress is different based on size, it also showed seasonality (Figure 16). That is, the price become less in July and August compared to September and October. Furthermore, its availability is also seasonal, i.e., not commonly harvested and processed in July and August (Figure 15).

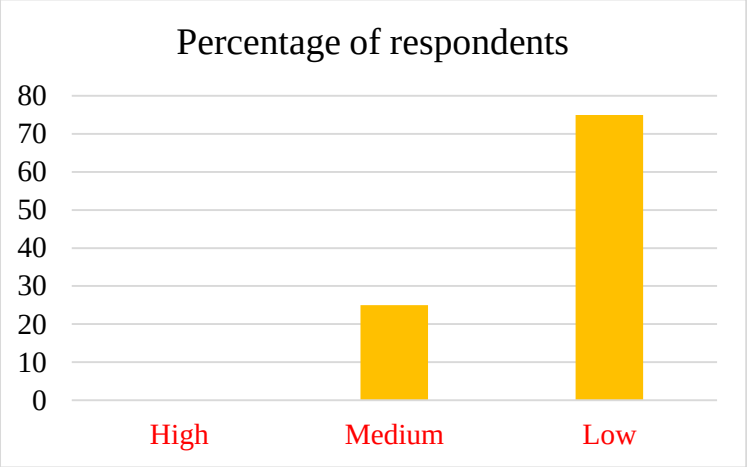

Figure 15. Vendor's response about the availability of *Cyperus papyrus* at Tikur Wuha wetland

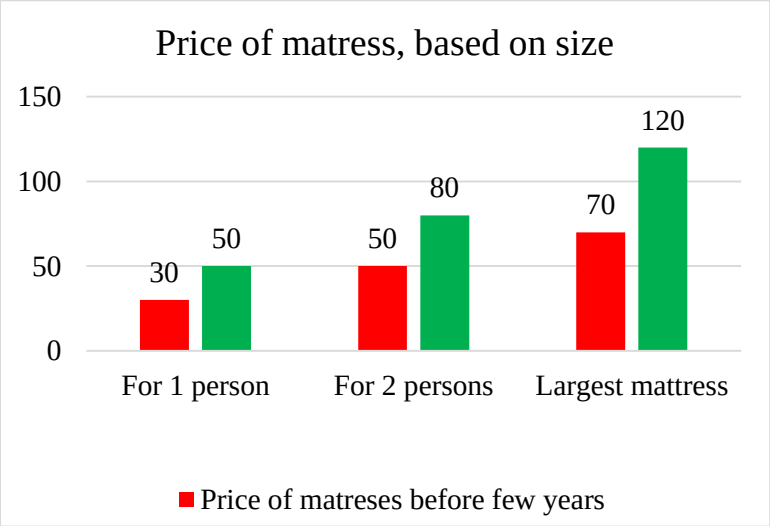

Figure 16. Market value of mattress in Tikur Wuha and Hawassa market.

CHAPTER FIVE

5. Discussion, conclusion and recommendation

5.1 Discussion

5.1.1 Population status of *Cyperus papyrus*

Different sites were sampled to study the recruitment status of the populations of *Cyperus papyrus*. Results showed populations with both mature and young individuals. Besides, some populations found devoid of mature or young individuals. There were also sites without representation of any *Cyperus papyrus*. Sites with no young individuals but only with mature ones were identified as prone to local loss due to overharvesting for making different kinds of products of this species. On the other hand, sites with only young plants are prone to human impacts as these could be harvested after maturing. This cycle of harvesting mature plants and young plants when they mature could potentially affect the reproductive potential and persistence of the populations.

In the study area, the farmers prefer to remove the plant to increase agricultural expansion. Herdsmen also bring their livestock to the water or to make their herds to graze on abundant grasses in the wetland particularly during dry seasons because they do not have any other alternatives. In this case, over grazing damages the young shoots of C. *papyrus.* (Pirot et al., 2001) leading to local losses of populations.

According to Auma (2016), the number of *Cyperus papyrus* population is decreasing mainly because more lands are put either to farming or settlement. This might have resulted in clearing of *Cyperus papyrus* and in the other way the rate of *Cyperus papyrus* utilization due to increase in human population. The traditional harvesting method may have also played a role in resulting in diminished populations of this species across the wetland. C. *papyrus* is usually harvested by cutting the stem at some meter above the ground, which means not only the mature *Cyperus papyrus* but also the young shoots are removed unintentionally. This harvesting approach is practiced in the study area and has resulted in poor regeneration and reduced number of young plants. In addition to this, farmers clear the plant to create space for farming then the farmers drain water out of the swamp and due to this problem the uproot *Cyperus papyrus* rhizomes stop regeneration. This might have resulted in land cover change where papyrus is replaced by crops. More crop yield is obtained from the swamp than terrestrial land because wetland soil is more fertile and contains enough water and moisture that sustains the

crops. This implies that improved farming practices which included irrigation and application of fertilizers to improve soil fertility may give high yields from terrestrial agriculture.

Local losses of the population of *C. papyrus* has a far reaching impacts on the reproductive success of other associated biodiversity such as fishes and amphibians. This species provides optimal niches for other animals to nest and forage at different trophic levels. Therefore, the complete removal of this habitat disrupts various ecological interactions and leads to biodiversity loss.

5.1.2. Physico- chemical characteristics of Tikur Wuha wetland

There are various factors affecting the health of Tikur Wuha and Lake Hawassa. Industrial effluents and agricultural activities such as drain and cultivate approaches are the major factors. Industrial effluents such as wastewater increase the amount of dissolved chemicals in the water. Heavy metals in the wastewater could result a negative impact to the environment through bioaccumulation (means an increase in the concentration of a chemical in a biological organism over time, compared to the chemicals concentration in the environment). Compounds accumulate in living things any time are taken up and stored faster than they are broken down or metabolized or excreted of toxic metals over long periods (Sekhar*et al*., 2003).

According to BireneshAbay (2007), Tikur Wuha wetland contained harmful chemicals, even the concentration of Conductivity, pH, turbidity and temperature were found to be higher than acceptable ranges of the provisional discharge limits set by the national regulatory body. According to Wej (2015), among the WHO's 10 chemicals of major public health concerns, four are metal or metalloid posing serious threats to our health. These are Arsenic, Cadmium, Lead and Mercury; because of their toxicity they are also listed in the national primary drinking water regulations. Even though the harmful chemicals are present through all part of the wetland, the presence of high density of *Cyperus papyrus* may ameliorate this effect by filtering (bio-accumulating) these hazardous chemicals.

According to EPA (2003) the guideline standards of textile wastewater limit values, the limits of temperature, electric conductivity and pH are 40°C, 1000µs/cm and 6-9, respectively. Dissolved oxygen is the amount of oxygen dissolved in the water. Dissolved oxygen levels drop 5.0 mg/L cause stress to aquatic life. Oxygen levels that go below 1.2 mg/L for a few hours may result in large fish kills and excess oxygen cause gas bubble and block the flow of blood through blood vessel (WWW, state. Ky. us/nrepc/ water/ wwhome pg.htm).

Whereas the amount of temperature, pH, electric conductivity, turbidity Total Nitrogen, Total phosphorous and amount of heavy metal (Arsenic) was low in areas with high population, these were very high in the samples which were taken from the areas without this species. The conductivity was much higher in the wetland from sparsely or low populated area than the larger densely populated area. Such high conductivity value is due to the high content of organic matter, ammonium ions and other salts in urban runoff (waste water). Depending on the result, the amount of conductivity value is less than limited value at high and low *Cyperus papyrus* populated area and the value more than the limited value which was mentioned by EPA is recorded for low *Cyperus papyrus* populated area in Tikur Wuha.

The reduction in the levels of turbidity along the wetland was manifested in the season due to presence of huge swampy areas in the wetland made of several species of wetland macrophyte, the one of which is *Cyperus papyrus*. Moreover *Cyperus papyrus* reduce turbidity using their root hairs which contain electrical charges that attract opposite charges of colloidal particles (when suspended solids with opposite charges pass through the root hairs they adhere on to the roots). Consequently they are slowly assimilated by the plant and microorganisms. In so doing it makes wetland systems to work as giant filters by removing suspended solids and dissolved nutrients pollutants from the water before it enter to the water (Mugisha *et al* ., 2007).

Yezbie Kassa *et al.,* (2014) reported that the greater ratio of plant population to the wetland volume can enhance the contact between plant roots and waste water resulting in a greater nutrient removal. The same study in Lake Tana showed that, *Cyperus papyrus* significantly influenced the rate of removal of nutrients in the waste water. *Cyperus papyrus* planted beds had markedly higher phosphorous, nitrogen and heavy metals removal. More shoots are developed by *Cyperus papyrus* possibly indicating differences in nutrient uptake.

When the plants ages increase their potential to uptake phosphorous and nitrogen is very high. This is due to the roots and rhizomes which have relatively high P and N uptake potential. The root rhizosphere of *Cyperus papyrus* has been showed to be well colonized by N_2 fixing bacteria and high rate of nitrogen fixation have been recorded intact root system of papyrus. The higher levels of nutrients in the rhizome are also expected because of its storage function (Francis, 1997). On the other hand, the result show that the amount of total phosphorous and Arsenic is low in no *Cyperus papyrus* populated areas than low *Cyperus papyrus* populated areas, (the is a little value difference) and this is because in the low populated area more number of plants were matured C. *papyrus* the other study noted that nutrients stored by the plants of

young shoots are translocated to metabolically active sites when the environmental conditions are optimal for growth. Which means the youngest ones have faster growth and for that they use nutrients effectively than the matured ones and also the matured plants have low uptake potential (Francis et al., 1997).

5.1.3. Uses of *C. papyrus* and knowledge transfer

The results show that local people of the Tikur Wuha wetland area learnt the importance of *Cyperus papyrus* and adopted it as a source of household income. People of different ages, education levels and occupation appreciate the value and usages of *Cyperus papyrus*. Young people learned making mattress through trial and error and from elders. For the youth, *C. papyrus* presents job opportunities. Most commercial usage of *Cyperus papyrus* in the study area is mat production which is similar to those reported by Josiah (2000).

The other uses of *Cyperus papyrus* at Tikur Wuha are for medicinal, house hold material construction, boat making, mat making, house construction, for rituals (spiritual ceremonies), decoration in recreational sites, fire wood, fodder and also for fish trapping. Such uses were in the ancient Egypt, Rome Empire and elsewhere (Lind and Marrison, 1974). *C. papyrus* shoots are used as fuel wood this finding is similar to the study from Rwanda (Kabii, 1996). Utilization of *Cyperus papyrus* for medicinal purpose is not common in the study area Tikur Wuha wetland but this has been reported elsewhere (Duke, 1983), i.e., the species was used to cure ailments in historical times (i.e. up to200 AD). Examples are, the pith was recommended forwidening and drying of fistula; the ash of burnt *C. papyrus* sheets was used for certain eye diseases. But in the study area, a mixture of the inflorescence and butters is used for treating the burnt part the body.

Cyperus papyrus provides alternative incomes for the people. The scarcity of this natural resource has a profound effect on the livelihoods of the local communities. This condition directly affected the production of mats, where few mat makers can get little materials and hence produce less mats finally the market price become very high from time to time (Josiah, 2000).

Traditional knowledge transfer in Tikur Wuha town is very low so a rich knowledge of plant has also disappeared, since this knowledge was not properly passed down to the next generation through earlier specialized healers. These fact may be one of the influence on the medicinal value of *Cyperus papyrus* being not well known and not more applicable in the study area and

they used to heal only for one thing and also the young generations are learning more from the society and mainly through oral approach and now a days the existing knowledge is not yet properly documented in a written form. According to Mirutse Giday(2001) healers had a strong tendency of keeping their knowledge secret and died without releasing the information to anybody. Results on indigenous knowledge of people on *C. Papyrus* depict that elders are more knowledgeable than the younger ones.

The young generation is more declining to believe in modernisation of medical care or modern education so most of them are not interested to know and practicing traditional medicine. For example in Nepal, the negative effects of modernisation has been widespread and elders only know full information and the younger doesn't give any sense about it (Manandhar, 1995).

5.2 Conclusion

Tikur Wuha wetland is one of the Lake Hawassa influent, which is also used as a bridge in order to separate Oromiya and SNNPR. This study observed that *Cyperus papyrus* is one of the plants found in this area and the local peoples use it for different cultural and economic purposes such as medicinal, making house hold material, boat making, mat making, house construction, for rituals (spiritual ceremonies), decoration in recreational sites, fire wood, fodder and also for fish trapping. Mattress production here in Tikur Wuha is one of the money maker (income) production for the local people but now a days the mattress production is going down because of the number of *Cyperus papyrus* in the wetland is declining due to various factors. The declining factors include over grazing, agricultural practices around the wetland, improper harvesting techniques and other. The number of new generation plant population is lower than the matured so the existing destruction is a pressing factor even for the presence of *Cyperus papyrus* in the coming years. All these factors do have an impact even on income generation of the local people partly relying on *C. Papyrus* products.

Physico- chemical results from the study showed that most of the parameters such as Turbidity, Dissolved oxygen, pH, conductivity, Temperature, N, P and As are all above reference value and the provisional standards set out by EPA. Especially at the area of no *Cyperus papyrus* populated area, compared to low and high populated area. Therefore the data generated from this study gives some insight for the potential uses of these plant for nutrient and heavy metals removal in wetlands and their application as an alternative waste water treatment system.

5.3 Recommendation

Environmental conservation is a key issue and *Cyperus papyrus* use should be sustainable hence minimizing the effects that cause its destruction. The study come up with the following recommendations which are important for the sustainability of *Cyperus papyrus*, water purification, the continuity of animal's activity inside the water and generally for the wetland ecosystem.

- To help compensate for loss of papyrus, alternative sustainable livelihood and development options need to be considered by the stakeholders including recreation site owners, research and educational sites, local peoples and city administrators, non-governmental organizations. Involvement has to be promoted through empowerment in skills development, education, public awareness and information exchange. This will also increase their level of participation in conservation activities but the best way for conservation and general management of the *Cyperus papyrus* as well as wetland is through making the local people become the owner of all activities inside the natural environment and the administrators should have to let them to use it and get income.
- Promotion of ecotourism by the government in the area will help to create employment, provide market for the materials made from *Cyperus papyrus* and generate income to the local community and the entire nation.
- The stakeholders should prepare the land policies and work on its application.
- Environmental standards with their protocols should be followed with strict enforcement measures.
- The stakeholders should have to be pre requisite to require textile industries to continuously monitor textile effluents and take necessary actions to change wastewater to environmentally friendly form before discharging it into Tikur Wuha River.

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Appendix 1

Oral concept script

My name is Hiwot Fiseha. I am conducting a research on population status, ecology and Ethnobotanical uses of *Cyperus papyrus* (papyrus) in Tikur Wuha wetland, Southern Ethiopia. Before we begin, I want to explain my research activities, answer any questions you have, and make sure I have your permission to continue. The main purpose of this research is for academic education, therefore, today I would like to ask you about the uses of Cyperus papyrus in your area. Of course your participation is voluntary. You do not have to answer any question you do not wish to answer. We do not anticipate any risks resulting from your participation in this research. This study will directly or indirectly enhance your access to a wide range of information of Cyperus papyrus. You will become part of the research that works towards allowing the protection of Cyperus papyrus and the lake resources. You can tell me that you no longer wish to participate at any point.

Provide contact information and allow time for questions

Before we continue, I need to make sure that I have your permission to carry out the research in your area.

Do you consent to your participation in this research?

Appendix 2.

Field interview data collection format

Date of data collection_____

Name of interviewer_____

Name of language translator _____

Checklist of semi-structured questions to be used as basis for discussion and interview for informants to collect Ethnobotanical information on *Cyperus papyrus.*

I. General information of the study area

Informant's name_____ Age_____ Sex_____

Location Region_____ Zone_____ Woreda_____ Kebele_____

Education background_____

Marital status_____

II. Ethnobotanical uses of *Cyperus papyrus*

1. Do you use *Cyperus papyrus*? if Yes, for which purpose do you use it?

   _____

   _____

2. Which part of the plant do you use it? _____
3. Are the community members use *Cyperus papyrus* frequently? If Yes, Why?

   _____

   _____

4. For which purpose more do you use Cyperus papyrus?

   _____

   _____

5. How does the knowledge transfer from the elders to younger generation?

   _____

   _____

6. What is the local name of *Cyperus papyrus* in your area? _____
7. Do you have anything else to tell me?

   _____

   _____

Thank you very much for your cooperation !!

Appendix 3.
Ethnobotanical market place data collection format of Cyperus papyrus

Location of market place_____

Name of data collector_____

Date of collection_____

Name of language translator_____

I. Information of vendor

Name of seller_____ Age _____Gender_____

Location region_____ Zone_____ Woreda _____Kebele_____

Market name_____

- What is the market status of *Cyperus papyrus?*

  _____

  _____

- What is the price? _____
- How much sold now compared to in the past? A. more B. same C. less

  If less, Why?

  _____

  _____

- In which month the price become less and Cyperus papyrus become more available?

  _____

- Where do you get the production? _____
- Are there males or females make the products? _____
- Which product of Cyperus papyrus is more preferable by the people?

  _____

- Which part is used for market? _____
- Frequency brought to market: daily, weekly or on accession.

  _____

Thank you for your time !!

Appendix. 4.
Physico-chemical result

S/N	ID	Mg/L				µg/L	
		TP	TN	Cd	Pb	As	Hg
1	S1	ND	2.72	ND	ND	0.89	ND
2	S2	2.24	7.50	ND	ND	11.03	ND
3	S3,S3	1.54	7.23	ND	ND	10.14	ND
4	S4,S4,S4	2.01	5.60	ND	ND	12.59	ND

S/N	Tests	Test Methods
1	**Total Nitrogen (TN)**	APHA 4500-Norg C. Semi- Micro Kjeldhal Method
2	**Total Phosphorous(TP)**	APHA 4500-PE. Per sulphate digestion-Ascorbic acid colorimetric
3	**Total Mercury(Hg)**	APHA 3111C. AAS, cold vapour technique
4	**Total Arsenic(As)**	APHA 3112B. Cold Vapour Atomic Absorption Spectrometry Method
5	**Total Cadmium(Cd)**	APHA 3111C. Air- acetylene Flame Method
6	**Total Lead(Pb)**	APHA 3111C. Air- Acetylene Flame Method

Declaration

I, the undersigned declare that this Thesis my original work and it has not been presented in other universities , colleges and institute for a degree or other purpose. All sources of the materials used have been duly acknowledged.

Name	Signature	Date
Hiwot Fiseha	_____	_____

This work has been done under my supervision.

Name	Signature	Date
Dr. Bikila Warkineh	_____	_____
Prof. Sileshi Nimomissa	_____	_____
Dr. Ermias Lulekal	_____	_____