Wetland Vegetation Composition and Ecology of Abaya and Chamo in Southern and Fincha'a-Chomen and Dabus in Western Ethiopia

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Abstract

Wetland Vegetations of Chamo and Abaya Lakes in the southern and Fincha'a-Chomen and Dabus marshes in western Ethiopia were studied to determine floristic composition, vegetation ecology, plant community types and to identify environmental factors significantly influencing the distribution of plant species and community types. A total of 339 relevés were laid along transects that were set up preferentially across areas where there were rapid changes in vegetation or marked environmental gradients to collect data on estimate of percentage aerial cover of plant species and environmental variables. A total of 302 plant species belonging to 194 genera and 72 families were identified. The most dominant families in all the sites were Asteraceae, Poaceae, Cyperaceae and Fabaceae. Multivariate data analyses were performed using appropriate packages in R version 2.14.0. Vegetation data were analyzed by agglomerative hierarchical cluster analysis using similarity ratio as a resemblance index and Ward's linkage method. Canonical Correspondence Analysis (CCA) was used to explore the relationship between the species composition and environmental variables. The environmental data to be included in the CCA were determined using stepwise backward and forward selection of variables by ANOVA test. Statistical measurement regarding species diversity, richness and evennèss of the plant community types was carried out by using Shannon-Wiener (1949) diversity indices. Sample-based rarefaction curves were computed in the program EstimateS (Colwell, 2005) to estimate and compare species richness across sites of different sizes. Comparison of the floristic diversity of the wetlands showed that Dabus marsh had the highest alpha diversity. From all the study sites, relatively the highest number of plant community types was recorded from wetlands of Lake Abaya during both seasons. The most important factors influencing the plant species composition and pattern of wetland plant communities were drainage, water depth, land use, slope, altitude and hydrogeomorphology (in wetlands of Lake Abaya) and water depth, disturbance and hydrogeomorphology (in wetlands of Lake Chamo). All of the measured factors had significant role in Dabus and Fincha'a-Chomen marshes. Therefore, these should be

considered in future management and protection under the circumstance of climate change and human activities.

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List of Acronyms

CCA - Canonical Correspondence Analysis

MRPP - Multiple Response Permutation Procedure

EMA- Ethiopia Mapping Agency

EPA- Environmental Protection Authority

H.W.R.D.O. - Horo Wereda Rural Development Office

GWSPMFRDA - Gimbi Woreda Strategic Plan and Management for Rural Development and Agriculture

IBC - Institute of Biodiversity Conservation

NAE - National Atlas of Ethiopia

EMSA - Ethiopia Meteorological Services Agency

EFAP - Ethiopian Forestry Action Program

EWNHS - Ethiopian Wildlife and Natural History Society

CSA- Central Statistical Authority

MoARD - Ministry of Agriculture and Rural development

IBA – Important BirdLife Areas

DGA – Direct Gradient Analysis

ANOVA – Nanalysis of Variance

GPS – Global Positioning System

SNNPRS – South Nations Nationalities and Peoples Regional State

IUCN – International Union for Conservation of Natural Resources

WBISPP - Woody Biomass Inventory and Strategic Planning Project

FAO – Food and Agriculture Orgamization

OECD - Organisation for Economic Co-operation and Development

CHAPTER ONE

1. INTRODUCTION

1.1. Wetlands

1.1.1. Definition, Classification and Distribution of Wetlands

There is no single, correct, indisputable, ecologically sound definition for wetlands, primarily because of the diversity of wetlands, partly because of their highly dynamic character and because the demarcation between dry and wet environments lies along a continuum which results in difficulties in defining their boundaries with any precision (Cowardin *et al.*, 1979). Wetlands are areas where saturation with water is the dominant factor determining the nature of soil development and the types of plants and animals living in the soil or on its surface (Philipose and Thomas, 2003). The United States Fish and Wildlife Service defined wetlands as lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface of the land or the land is covered by shallow water (Cowardin et al., 1979; Niering (1997). Wetlands have often been described as being ecotones, i.e., they act as transitional zones between upland areas such as forests and farmlands and deepwater aquatic systems such as rivers, lakes and estuaries (Mac *et al.,* 1998; Hook, 1993; Mitsch; Gosselink, 2002).

The definition of the Ramsar Convention is one of the broadest definitions available which is recommended by IUCN and other international agencies involved in wetland conservation and management and therefore mostly used on international scale. The Ramsar Convention (Article 1.1) defined 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 6 meters*" (Ramsar Bureau, 2005). This definition encompasses a wide range of diverse landscapes whereby three inherent components of a wetland are manifested: water, hydric soils and hydrophytic vegetation. Ramsar definition covers a broad range of wetlands that includes lakes and rivers, swamps and marshes, wet grasslands and peat lands, estuaries, deltas and tidal flats, near-shore marine areas, mangroves and coral reefs and human-made sites such as fish ponds, reservoirs, and salt pans.

Similar to wetland definition, there is no universally agreed classification of wetland types, and these vary greatly in both form and nomenclature between regions. Wetlands differ in their soil, landscape (topography), climate, Hydrology (water regime), water chemistry, vegetation and human disturbance. Hydrological processes are widely recognized as the most important determinants of wetland functions and values (NRC, 1995). The source of water also determines the wetland types. They are composed of highly contrasting but interlinked habitat types such as those which occur across the hydrological gradients of river flood plains or lake margins. The generic system produced by Cowardin *et al.* (1979) for the United States Department of the Interior is based on such factors as: salinity and pH; the characteristic vegetation and dominant plant species; the frequency and duration of flooding; and the organic or mineral composition of soils. According to Cowardin *et al.* (1979), five major wetland types are recognized: namely, marine (coastal wetlands including coastal lagoons, rocky shores, and coral reefs); estuarine (including deltas, tidal marshes and mangrove swamps); lacustrine (wetlands associated with lakes); riverine (wetlands along rivers and streams); and palustrine (marshes, swamps and bogs). Although the Cowardin *et al.* (1979) approach has provided the basis for simplified methodologies and has been adapted for use by the Ramsar Convention (Scott, 1989), this classification system does not include man made wetlands and wetlands associated with agricultural lands.

In Africa, marshes and swamps are often defined and characterized in similar manner and the words are used interchangeably. They are defined as wetlands frequently or continually inundated with water, characterized by emergent soft-stemmed vegetation adapted to saturated soil conditions. They are dominated by herbaceous vegetation and are characterized by very wet soils during the dry season and standing water during rainy season (Howard-Williams and Gaudet, 1985). A fundamental requirement, however, remains the need for a functional classification of wetlands and considerable scientific effort is now being directed towards that goal (Simpson *et al.*, 1998).

According to Cowardin *et al.* (1979), wetlands have three major attributes. These include: hydrophytic vegetation, hydric soil and hydrology. The bottom of wetlands, at least periodically, supports predominately hydrophytes i.e. it supports vegetation adapted to the wet conditions. It favours particular type of trees, shrubby species and associated herbs, sedges and grasses. The substrate is predominately undrained hydric soil, i.e., they often have unique soil conditions or hydric soil that differs from adjacent uplands. The substrate is saturated with water i.e. they are distinguished by the presence of water (hydrology), either at the surface or within the root zone.

Wetlands are distributed all over the globe and estimated to cover about 6% of the earth's surface (Maltby, 1986). But, a more recent estimate of the world's wetlands by the U.S. Department of Agriculture (Brinson and Diane, 2011) states that 13.7% (18.8 million km^2) of the earth's surface is wetland. Although Africa is best known for its savannahs and hot deserts, 1% of its surface area (345,000 km^2) is covered by wetlands (Finlayson and Moser, 1991).

1.1.2. Values and Loss of Wetlands

Irrespective of the size and spatial distribution, wetlands provide a wide range of important values and functional attributes. Wetlands are among the most important productive ecosystems on earth because of the complex interactions between biotic (fauna, flora, microbes and unicellular organisms) and abiotic (soil, water and topography) components of wetland ecosystems (Mitsch and Gosselink, 2002; Costanza *et al.,* 1997). Wetland ecosystem is considered to be more productive than the adjacent area because of the periodic inflow of nutrients. Their productivity is comparable to rainforests and coral reefs (Costanza *et al.*, 1997). They constitute a resource of great economic, cultural, scientific and recreational values. Schuyt (2004) estimated that freshwater wetlands hold more than 40% of the entire world's plant species and 12% of all animal species. Finlayson and Moser (1991) estimated that more than 40% of fishes (of the 20,000 species in the world) live in fresh water wetlands. Individual wetlands can be important in supporting high numbers of endemic species; for example, Schuyt (2004) reported that Lake Tanganyika in Central Africa supports 632 endemic fishes and other animal species.

The diversity in functions that wetlands perform makes them incredibly valuable ecosystems. Wetland functions are the indirect services which wetlands provide to the society (water retention or storage, sediment or pollutant removal, habitat support). Wetland values are the direct services provided by wetlands to the society and may be either given a monetary or a relative value such as flood control, water quality and a recreational service (King *et al.*, 2000). Schuyt (2004) noted that wetlands have a very high ecological value, providing the water and primary productivity upon which countless species of plants and animals depend for survival. They also provide wetland products such as food, fuelwood, wildlife, fisheries, forage, and agricultural resources. Despite being associated with diseases such as malaria and schistosomiasis and livestock parasites such as liver flukes, wetlands provide food for the people and pasture for the livestock during periods of scarcity

Wetlands produce an ecological equilibrium in the environment by maintaining the integrity of life support systems for sustainable socio-economic development. Wetlands are also important sources of water for agricultural, industrial and domestic uses. They play important roles in ecological functions in their natural states, which contribute to the wellbeing of human society. Wetlands, especially river valleys and their associated floodplains have been sites of human civilization.

Mitsch and Gosselink (1993) described wetlands as the kidneys of the landscape because they function as the downstream receivers of water and waste from both natural and human sources. They stabilize water supplies, thus ameliorating floods and drought, erosion control, water flow regulation, water storage, ground water recharge, retention of pollutants, water purification, nutrient recycling, exchange of water between the surface and the ground water and the surface and the atmosphere (Oertli, 1993; Niering, 1997; Philipose and Thomas, 2003). Mitsch and Gosselink (2002) also described wetlands as lungs of the landscape because they act as carbon sinks and climate stabilizers on a global scale. They act as buffer systems between other aquatic systems and human activities on upland areas (Hook, 1993). Because of the extensive food chain and rich biodiversity they support, Mitsch and Gosselink (2002) called wetlands as biological supermarkets.

Despite the will in understanding of wetlands and their ecological importance, degradation of wetlands continues, mainly due to anthropogenic activities. About half the global wetland area has been lost as a result of human activities (OECD, 1996). In tropical and subtropical areas conversions of wetlands to alternative land uses have accelerated wetland loss and agriculture is considered the principal cause for wetland loss. Wetlands were drained to control disease and for agricultural activities (Maltby, 1986; Lean *et al.*, 1990; Mitsch and Gossenlink, 1993; Wetzel, 1975). Other important reasons for their vulnerability are the fact that they are dynamic systems undergoing continual change (Barbier *et al.*, 1996) and are the fact that they are often open-access resources with limited control over how they are used and what is harvested from them (Turner *et al.*, 2000).

1.2. Distribution and Types of Wetlands in Ethiopia

In Ethiopia, wetlands are distributed across all agro-ecological Zones from high altitude of 4000 m above sea level to 125 m below sea level (Afework Hailu *et al.*, 2000). The different geological formation, ecological diversity and climatic conditions have endowed Ethiopia with all types of wetlands except coastal, marine-related wetlands and extensive swamp-forest complexes (EPA, 2003). These include alpine formations, riverine, lacustrine, palustrine, manmade reservoirs and floodplain wetlands (EPA, 2003). On the basis of wetlands categorisation under the Ramsar International Convention, EPA (2003) listed Ethiopian wetlands as fresh lakes, ponds, swamps or marshes, streams, riverine flood plains and manmade reservoirs.

Compared to other resources like land, water, livestock, the data and information on wetlands are very scanty and incomplete. Different estimates have been given regarding the total wetland area of the country. According to Dugan (1990), the total area of wetlands in Ethiopia may exceed 2% (22,500 km^2), a figure that corresponds with the estimated remaining forest area coverage of the country. According to the FAO (1990), swamps and marshes are the dominant wetland types in Ethiopia while the EPA (2003) report shows that seasonally inundated flood plains occupy the largest share of the wetlands, followed by freshwater lakes, swamps and marshes. Floodplains are found both in Ethiopia's highlands and lowlands, although they are most common in the sourth-western and western highlands. Lakes are also widely distributed both on highland and lowland parts of the country (Figure 1.1) with the largest concentration in the great east African rift valley system (EPA, 2004).

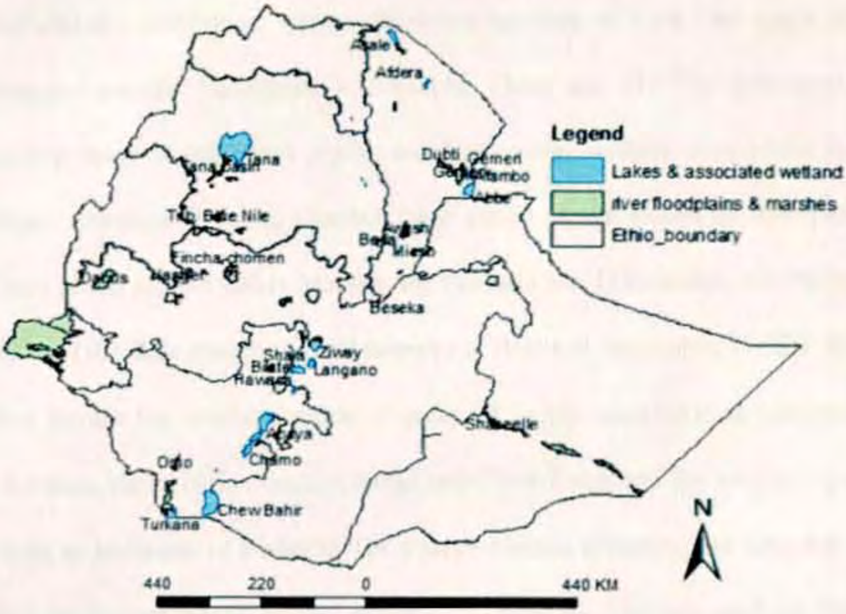


Figure 1.1: Map of Ethiopia showing lakes, rivers and associated wetlands

Using the directory of African wetlands, Hughs and Hughs (1992) classified Ethiopian wetlands into ten major groups including tidal and coastal wetlands although Ethiopia has no access to the sea. These are: (1) wetlands of the Bale Mountains; (2) wetlands of Lake Tana; (3) Lakes of Bishoftu; (4) Lakes of the southwest rift valley; (5) Lakes and swamps of the Awash River system; (6) Lakes of the Danakil depression; (7) River floodplains; (8) Artificial impoundments, (9) Tidal and coastal and (10) Other wetlands. This classification system is based mainly on river and lake drainage systems. Moreover, it does not give complete list of Ethiopian wetlands and is not able to cope with the many different forms of wetland such as fresh or seasonal. The classification scheme is, however, able to show the diversity of wetland types in the country.

Solomon Tilahun *et al.* (1996), regrouped Ethiopian wetlands into four major categories (Figure 1.2) based on ecological Zones, hydrological functions, geomorphologic formations and climatic conditions. These categories interlink to form four major biomes, which also describe climatic conditions in Ethiopia. These are: (1) The Afro-tropical highlands that include most of Ethiopia's alpine and fresh water wetland ecosystems such as lakes Tana, Hayk, Ashange, Wonchi; Dembia flood plains on the shores of lake Tana; Chomoga-Yeda flood plains around Debre Markos, the Borkena and Dillu swamps in the upper Awash basin; lakes of the Bale mountains and swamps of Arsi and Haramaya, (2) The Sommali-Masai type that include the southern group of great rift valley lakes such as Langano, Abijatta, Shalla, Hawassa, chelekleka, Abaya, Chamo and Chew Bahir and the northern groups of the Awash basin as wetlands of Bishoftu, the Kesem-Meteka complex and lake Abe complex, (3) The Sudano-Guinea found in the western lowlands of Ethiopia such as Baro-Akobo, Dabus, Belese and Tekeze floodplains, and (4). the Sahelian transition zone groups that include fresh and saline wetlands found in the extreme north-eastern part of Ethiopia (including Lakes Afambo and Afdera).

Figure 1.2: Map of Ethiopia showing the four categories of wetlands by biome (source: Yilma Abebe, 2003)

1.3. Values of and Threats to Wetlands in Ethiopia

Although wetlands in Ethiopia cover only a small area, they have immense economic, social, and environmental benefits. Wetlands are the main sources of valuable water resources in Ethiopia, where water resources are unevenly distributed and only a quarter of its population has access to safe water. In many parts of Illubabor and Wollega, many perennial and annual springs are associated with the existence of wetlands. Throughout the country, wetlands are important sites for livestock and wildlife grazing especially during the dry period. Floodplains of Borkena, Dabus (Appendix 6) and Fogera are vital sources of fodder, particularly during dry season, to both domestic and wild animals.

Wetlands are also vital sources of food, fuelwood, and raw materials for making household furniture. Growing number of people in our country, in both rural and urban areas depend on wetland resources for their survival. Poor rural households, particularly women depend on wetlands for additional income to their families. In the ethnic group known as the 'Agnuak' in the Gambella lowlands along banks of the Baro and Gello Rivers, women are heavily involved with fishing activities (Afework Hailu *et al*., 2000). Many peasant farmers in the western parts of the country make their living from wetlands. Sedges are one of the important wetland resources that local communities use in different parts of the country. For example, in western Oromia, sedges have great importance for thatching of houses (Afework Hailu *et al*., 2000). More than three fourth of the local households in Illubabor Zone (Afework Hailu *et al*., 2000), use sedges for roofing their houses.

Wetlands support a great deal of flora and fauna, including many endemic bird species. Wetlands support useful non-cultivated plants such as species of *Discorea, Erythrocarpus, Celtis tokka, Tamarindus indica, Ficus sur, Carissa spinarum, Cordia africana, Gardenia ternifolia, Citrus auriantifolia, Ipomoea aquatica*, and *Nymphaea lotus and Nymphaea nouchali* that are used by people for food in the Baro-Akobo (Tesfaye Awas *et al*., 1997), Awash Valley (Mitiku Tikssa, *et al*., 2010) and Cheffa area in Wello (Bayafers Tamene *et al*., 2000).

Wetlands of Abaya and Chamo lakes provide range of ecological and economic importance to wildlife and people in the surrounding area. The wetland vegetation is an important nesting and feeding areas for hundreds of wetland birds and hippopotamus and protective shelter for spawning areas for crocodiles (Appendix 7). Dabus wetland in western Ethiopia also supports hundreds of hippos (Appendix 7). Wetlands of Rift Valley Lakes are sites for tourist attraction. Wetlands can be sites for investment, such as the crocodile farm in Arba Minch, sugarcane farming in Fincha'a, livestock and crop farming in and around Borkena wetlands.

Despite the global importance, wetlands in Ethiopia are still facing many problems. The major threat comes from the over harvesting of wetland resources, the expansion of human settlements in the main Ethiopian Rift Valley Lakes (Ziway-Shala, Hawassa, Abaya-Chamo and Chew Bahir basins), the construction of dams in Koka and Melka-Wakana, drainage for agriculture in southwest Ethiopia especially in Jimma and Wollega Zones (Afework Hailu *et al.*, 2000).

Wetland resources such as water, fishes and vegetation are subjected to over exploitation. Excessive exploitation of the resources from wetlands can lead to a direct collapse of the wetland and its resources. Disappearance of Lake Haramaya wetlands through excessive use of water for irrigation can be an evidence to demonstrate overuse of a resource from wetlands.

Threats to wetlands also originate from the catchments since wetlands are closely interacting with the catchment. Wetlands in the lowland areas are threatened by encroachment due to shortage of cultivation and grazing areas that results from population pressure in the highlands. Overgrazing by livestock and wildlife leads to loss of biodiversity and compaction of the wetland soil during wet periods (Appendix 6) which can affect infiltration capacity of the wetland soil. This can in turn affect biodiversity of the wetland. In other instances, catchments are the source of agricultural discharges and will result in increased nutrient load to the wetlands (eutrophication) which leads to the colonization (homogenization) of the habitat by single species which are usually invasive (either exotic or indigeneous species). Invasive species are a major threat to global biodiversity and an important cause of biotic homogenization of ecosystems (Enserink, 1999). Invasive species, either exotic or indigeneous, are also threats to wetlands of Ethiopia. Examples of invasive species threatening Ethiopia's wetlands include *Prosopis juliflora* in Awash River basin, *Mimosa pigra* in the Baro-Akobo basin, and water hyacinth, *Eichhornia crassipes,* in Koka reservoirs (Tesfaye Awas *et al.*, 1997; Mitiku Tikssa *et al.*, 2010; Bayafers Tamene *et al.*, 2000).

Increased accumulation and sedimentation will ultimately accelerate the rate of conversion of the wetland system to a terrestrial one (Wetzel, 1975).

The low level awareness of communities regarding the benefits of wetlands, capacity limitations such as lack of skilled manpower, scarcity of wetland focused and coordinated institutions, lack of technical and financial support for wetlands conservation also accelerate loss of wetlands.

1.4. Wetland Vegetation Types of Ethiopia

In a new atlas of the potential vegetation of Ethiopia that has been produced by Friis *et al.* (2011), three wetland vegetation types were described. These are: (1) Reverine vegetation, (2) Fresh-water lakes (the subtypes are fresh water lake or open water and fresh water marshes and swamps, floodplains and lakeshore vegetation) (3) Salt lakes (the subtypes are open water or salt lake and salt pans or saline/brackish and intermittent wetlands and salt-lake shore vegetation).

1.5. Problem Statement

Although 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, 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. Some of the key challenges to the wetlands of lakes Abaya and Chamo 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 (Seleshi Bekele, 2001). Overgrazing of lakeshore vegetation by livestock and overharvesting particular plant species such as *Aeschynomene elaphroxylon* for the construction of traditional boat, clearance of lakeshore vegetation and trampling due to fishing activities (Appendix 6) and deforestation in the watershed are also the main threats to the wetlands. The western parts of the two lakes are extensively used for big state farms, which were recently given for private investors. These include Arba Minch, Bilate and Sille state farms all of which are irrigated by rivers entering Lake Abaya and Chamo.

Drainage of wetlands for food production has been undertaken for decades in Wollega (Bognettean *et al.*, 2003). The existence of Fincha'a-Chomen and Dabus wetlands in western Ethiopia is threatened by human encroachment through subsistence farming, settlements, burning and plant biomass harvesting for livestock. These wetlands are highly threatened by the clearance of vegetation for grazing and agriculture (Appendix 6).

Despite their importance to 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 were in southwest Ethiopia with a focus on wetland management and policy implications (Afework Hailu *et al.*, 2003), hydrological impacts of wetland cultivation (Dixon, 2002; Dixon and Wood, 2003). Therefore; the vegetation ecology, species composition and diversity of wetlands in Ethiopia have not yet been in the detail it deserved. This is typically reflected in Lake Abaya and Chamo wetlands in south and Fincha'a-Chomen and Dabus wetlands in western Ethiopia where research in vegetation ecology, species composition and diversity have not yet been conducted.

Thus, this study was conducted with the purpose of determining the floristic composition, plant species diversity and richness, plant community types, trends in relationship between plant communities and ecological gradients and to find out the spatial and temporal distribution variations of wetland vegetation and to recommend some corrective measures of sustainable management. It is also hoped that this research can provide baseline information for further studies and the issues raised and recommendations given in the study areas will apply to the other wetlands in Ethiopia and neighbouring countries in the Horn of Africa.

1.6. Objectives of the Study

I. General objective

- The general objective of this study was to investigate floristic composition and vegetation ecology of wetlands of Abaya and Chamo lakes in the southern and Dabus and Fincha'a-Chomen marshes in western Ethiopia.

II. Specific objectives

- To determine the floristic composition, diversity and richness of the study areas,
- To distinguish the plant community types across the wetlands,
- To find the spatial and temporal variations of plant community types, composition and species diversity,
- To determine environmental factors influencing the plant community types, composition and plant species diversity in the study areas,

- To recommend ecologically sound strategy for sustainable utilization and conservation measures of wetland biodiversity (vegetation in particular) of the study areas;

1.7. General Research Questions

The following research questions will be answered in order to achieve the above objectives.

- How do the floristic composition, floristic diversity and richness vary in the study areas?
- Are ther different plant community types in the study areas?
- Do the floristic composition and diversity in the study areas show temporal variations?
- Which environmental factors are significantly influencing vegetation composition and plant species diversity in the study areas?

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Wetland Vegetation

Mitsch and Gosselink (2002) grouped wetland physical features into three basic elements: hydrology, soil and vegetation. Wetlands are distinguished from adjacent uplands by the presence of water (hydrology), either at the surface or within the root zone. Wetlands often have unique soil type (hydric soil) that differs from adjacent uplands. Wetlands support vegetation adapted to the saturated or anaerobic soil conditions. Wetland vegetation is the most important components for characterizing and defining wetlands (Mitsch and Gosselink, 2002). Wetland vegetation responds more readily to local edaphic factors such as the amount and periodicity of water rather than to macroclimatic and geological patterns across the landscape that dictates vegetation formation elsewhere. Drexler *et al.* (1999) stated that wetland vegetation typically exhibits a distinct pattern of zonation along the elevation gradient from open water to terrestrial. Pattern of wetland vegetation zonation along the elevation gradient in turn reflects gradients in oxygen supply, nutrient availability and toxin concentrations along the gradient from permanently flooded (open water) to seasonally flooded to terrestrial (Gosselink and Turner, 1978). The patterns of zonation also reflect species response to underlying environmental gradients but changes in species composition are not necessarily directed towards a single terrestrial climax (Mitsch and Gosselink, 1993; Breen, 1988).

The bottom of wetlands, at least periodically, supports predominately hydrophytes i.e. it supports vegetation adapted to the wet conditions. It favours particular type of trees, shrubby species and associated herbs, sedges and grasses. The substrate is predominately undrained

The stresses and problems that plants encounter in the wetland environment are so peculiar and in some cases so extreme that only highly specialized species or hydrophytes and species that are sufficiently equipped to deal with those stresses and problems can be found there, forming their own typical vegetation composition (Keddy, 2000). Typical wetland flora therefore consists of plants adapted to, or tolerant of varying degrees of inundation, and predictable patterns of vegetation distribution are often evident (Mitsch and Gosselink, 1993). Hydrophytes are palnts whose active photosynthetic parts are permanently or several months of each year, partly or wholly submerged in water, or plants which float on the surface water (Cook, 2004). They have the ability to grow, reproduce and compete in anaerobic soil conditions through morphological, physiological and reproductive adaptation. The adaptations include the presence of air pockets in the roots and stems, adventitious roots, shollow rooting systems, hypetrophied lenticels (large internal pores), as well as seed dispersal by water (Rogers, 1995).

Wetland vegetation condition is an important tool for monitoring wetland health. Kershaw (1973) pointed out that vegetation study may aid in the selection and implementation of appropriate conservation and management plans for sustainable use of ecosystems. Floristic data are relevant for establishing the present situation for environmental impact assessment and monitoring changes in ecosystem quality in terms of changing species composition (Groem *et al.*, 1994). The vegetation of wetlands is an important indicator of wetland quality and integrity (Morzaria-Luna *et al.*, 2004). The dominance of particular species of vegetation in the landscape may provide an indication of hydrological or water quality changes that have taken place. For characterizing wetlands, studies on wetland plant community (Harper *et al.*, 1999) and the role of environmental change in the community composition are fundamental (Ashley *et al.*, 2002). This is because each wetland has its own unique species community production and nutrient cycling (Gosselink and Turner, 1978). This results in spatial and temporal variations in the physical and chemical environment, creating different niches along both the horizontal and vertical dimensions to which plants respond (Mitch and Gosselink, 1993; Breen and Begg, 1987; Gosselink and Turner, 1978).

Moreover, there are environmental factors typical of a given type of wetland community. For example, plant communities of bogs are nutrient limited, whereas species of floodplains and marshes have to cope with mechanical stress due to inundation, flooding and grazing (Ellenberg, 1988; Esselink *et al.*, 2002; Dormann *et al.*, 2000). In addition, floodplain and marshes species often experience alternating wet and dry periods through the season, whose timing and duration may play an important role in the reproduction and regeneration of species (Bos *et al.*, 2002). The alternating wet and dry periods in wetlands naturally affect plant establishment from the seed banks by stimulating or inhibiting germination (Brock and Britton, 1995). Prolonged flooding or desiccation of the wetland ecosystem eliminates some species while favouring others (van der Valk, 1974). This has a significant effect on species composition of establishing plants (Casanova and Brock, 2000).

Kotze *et al.* (1994) described degree of soil saturation within a wetland in terms of three classes which correspond to the water regime with the dominant vegetation types associated to each class. These soil saturation classes and their vegetation types are: (1) permanently or semi-permanently saturated or flooded soils, characterised by reeds, sedges and/or bulrushes; (2) seasonally saturated or flooded soils, characterised by sedges and grasses; and (3) temporarily saturated or flooded soils, characterised by hygrophilous (plant growing in damp conditions) grasses. Plants intolerant of flooding are found in areas at relatively high elevation, while those more tolerant of flooding but less tolerant of prolonged dry periods are found in areas of less variable water levels at lower elevation (Breen and Begg, 1987). Areas subject to floods of shorter duration and depth are thought to have greater plant species diversity than those that are permanently flooded.

A number of authors (Tailing, 1992; Tekeuchi, 2005; Abila *et al.*, 2008; Stumm *et al.*, 2009) have highlighted the environmental disturbances as the major driving force in regulating plant species composition in wetlands. Adaptations to changing environment with phases of fluctuating events can subject a plant community to dominance by the most competitive species. Van Mooy *et al.* (2006) have shown that species diversity of wetlands can be affected by environmental disturbances to a point where the habitat is dominated by a few species. Wetlands are often located in parts of the landscape that receive and store very large and dynamic inputs (e.g., water, nutrients, sediment, propagules) from more elevated parts of the watershed. As a result, disturbances in upstream parts of the watershed will typically lead to disturbances in downstream wetlands (Zedler and Kercher, 2004).

Natural disturbance is an important factor shaping plant communities in wetland environment (Keddy, 2000). Some examples of typical disturbances in wetlands include waves, wind, water level fluctuations, flooding, ice scouring, and sediment or plant debris deposition. Disturbance may influence community patterns by indirectly altering the environmental and resource distributions, creating or defining opportunities for the establishment and persistence of new species; or reducing populations of established species (White, 1979).

Different studies indicated that there is interaction between hydrology and geomorphology in the development of wetland plant communities (van Coller *et al.*, 2000; Froend *et al.*, 1993; Janauer, 1997). The local topography of wetlands interacts with water regimes to determine how wetlands receive water during floods. Wetland morphology may modify certain aspects of water regime, such as the intensity of the inundation and the velocity of water flowing into a wetland. The number of turns and curves the water experience during flood and the slope of the wetland determine the velocity of water flowing into a wetland. Straight channels may experience higher water velocities than more curved ones (Amoros and Bornette, 2002). The frequency and intensity of inundation determine the composition of wetland plant communities (Amoros *et al.*, 2000). High velocity flows into wetlands cause sediment deposition that impedes the establishment of wetland vegetation by breaking and uprooting plants (Bornette *et al.*, 2008). Low velocity flows on the other hand, often deposit finer sediments impeding seed development through deep burial (Bornette *et al.*, 2008).

Human factors have a very fundamental influence over plant species composition of wetland environments (Allen *et al.*, 2005 and Abila *et al.*, 2008). Anthropogenic disturbances that alter wetland physical features either directly within wetlands or indirectly by off-site water level or watershed alteration can alter wetland plant community composition (Zedler, 2005). Gichuki *et al.* (2001) showed that there are strong relationships between environmental quality and vegetation composition and abundance with strong coupling effects being in those areas that are prone to anthropogenic disturbances in the catchment of a water body. Burns and Schallenberg (2001) indicated that agriculture, fire and livestock grazing in wetlands lower species diversity. Habitat influences such as clearing land for cultivation, construction of settlements or draining wetlands by man degrade the habitat and can cause local extinction of some species, thus reducing habitat and species diversity (Primack, 1993).

Worldwide, the most potent forces acting on vegetation are the effects of changing land use arising from both the direct effects of an expanding human population (e.g. habitat destruction for agriculture, human settlement, overgrazing, etc.) and indirect effects (e.g.

pollution) (Wilson, 1994). Land-use is the manner in which human beings employ the land and its resources for agriculture, grazing, logging, etc (Brandon, 2001). In the event of habitat loss and changes in habitat configuration (patch size and isolation), species presence could be affected (Andrén, 1994; Fahrig, 1997). Ecological dynamics in human influenced landscapes are strongly affected by socio-economic factors that influence land-use decision making (Berry *et al.*, 1995). Throughout the world, many shifting land use patterns are driven by a variety of social factors which result in land cover changes that affect biodiversity (Grootjans *et al.*, 1985).

2.3. Plant Community Concept

Classification of natural ecosystems into potential plant communities is an important tool for the long-term management of natural resources (Daubenmire and Daubenmire 1968; Pfister and Arno, 1980). Plant communities are defined as an assemblage of functionally similar species populations that occur together in time and space (Magurran, 1988). A plant community is an organized complex having typical composition (floristic aspect) and structure (morphological aspect) that result from the interaction through time. One of the characteristics of a community is its physiognomy, the way it appears. Physiognomy is largely a product of the predominant life forms of the organisms composing the community (Cain and Castro, 1959).

Kent and Coker (1992) view plant community as the collection of plant species growing together in a particular location that show a definite association or affinity with each other. Plant association is characterized by combination of different characteristic species, having a defined floristic composition in one association than the other (Andreucii *et al.*, 2001). The reason that certain species grow together in a particular environment might be because they have relatively similar requirements for existence in terms of environmental factors such as light, temperature, water and soil nutrients. They may also share the ability to tolerate the activities of animals and humans such as grazing, burning, cutting or trampling (Kent and Coker, 1992). On the contrary, if they have exactly similar requirements, there will be severe competition and replacement of the weaker by the stronger. Regarding the structure of plant communities two different views have been presented in the past. These are organismic (discrete) and individualistic (continuum) community concepts.

2.3.1. The Organismic (Discrete) Community Concept

Clements in (1928) considered plant communities as discrete units that can be recognized, identified and defined, which repeated themselves with great regularity over a given region of the earth's surface. The plant communities are considered super organisms that have their own life and structure as well as their own temporal and spatial limits (Chapman and Reis, 1992; Brown and Lomolino, 1998). The discrete community unit theory implies the existence of distinct communities (Walter, 1971). The distinct vegetation of each area represents a distinct community, which is separated by sharp vegetation transition from other communities (Ricklefts, 1997).

Within this community unit concept, the plant community is the basic unit, and may be represented by a group of relatively homogeneous samples classified based on floristic similarity into a hierarchical table (Palmer and Van Staden, 1992). Moreover, this view regards communities as having a degree of internal organizations, which jointly modify the environment with sharp delimitation from other environments. Therefore, the existence of each community could be attributed to the competition and exclusion of other less competitive ones by few dominant species (Roberts, 1987; Paul, 1993).

Species belonging to a community are closely associated with one another implying, the ecological limits distribution of each species will coincide with the distribution of the community as a whole (Burbour *et al.*, 1987). The discrete community concept predicts that the distribution of species along certain gradients, groups of species or communities would replace one another (Shipley and Keddy, 1987). Within each grouping, most species have similar distributions and the end of one group coincides with the beginning of another (Shipley and Keddy, 1987).

2.3.2. The Individualistic (Continuum) Concept

Contrary to the discrete community concept, Gleason's (1926) viewed plant communities as continuous entities. Plant species respond individually to variation in environmental factors and those factors vary continuously in both space and time. Every species has a different distribution or tolerance range and abundance. The assemblage of plants growing in an area is not only the result of environmental conditions but also species migration (Lewis and Tayler, 1997). The success of these species depends on the combination of environmental factors at that site and the tolerance range of the invading species. Gleason (1926) argued that the range of permutations of combinations of environmental factors together with the different tolerance ranges of the species, would always give a different combination and abundance of species. In this concept communities replace one another (Cloessen *et al.*, 1994) and distribution of one species within each group has similarity and the end of one group becomes the beginning of another.

The continuum concept suggests that plant community change (in their composition) gradually along the complex environmental gradients and hence identification of distinct community association is not possible (Collins and Roberts, 1993). The distribution centres and species range boundaries are widely scattered so that no groups of species would aggregate to form a distinct community unit (Burbour *et al.*, 1987). Rather each species has its own physiological tolerance limit to environmental variables and the environmental variables would also fluctuate and vary across partial scales (gradients). Both concepts emphasize an environmental factor giving little attention to the modification effect of the vegetation and their subsequent influence on the pattern of community (Roberts, 1987).

Collins and Roberts (1993) argued that the dichotomy should be avoided since both hypotheses do not exhaust the natural community patterns but they are competing rather than complementing as well as dealing with a special case of dynamic system. Collins and Roberts (1993) developed the hierarchical continuum concept, with regard to the distribution patterns of plant communities. The hierarchical continuum concept attempts to incorporate both hypotheses and assumes that some species will have a wider distribution, others localized, and still some others will have a much restricted distribution across the sample area. Hence, the distribution pattern and abundance of species assumes a hierarchical structure where species with wider, intermediate and restricted distribution ranges show some kind of hierarchy than a continuum or discrete.

2.4. Techniques for Analyzing Vegetation Data

2.4.1. Classification

Classification relies on defining a set of classes in which members of the same class and those of different classes with the intention that similarity is a matter of degree. Thus, similar properties shared by different classes and other properties that are not shared commonly serve to identify that particular class. Classification begins with the assumption that communities of discrete entities. Classification involves arranging stands into classes, the members of each class having in common one or more features setting them apart from the members of other classes (Greig-Smith, 1983).

Classification can be hierarchical or non hierarchical. Non-hierarchical classification divides samples into a number of clusters. Groups have no joint structure. The aim of such techniques is to produce the most efficient groups regardless of the route by which they are divided (Greig-Smith, 1983). If homogeneity of a group is of a prime importance in the application process, the non-hierarchical techniques are best fit.

Hierarchical classification techniques define relationships among the clusters. Samples having the same properties are arranged into classes at any level are subclasses of classes at higher level (Pielou, 1969). A hierarchical classification technique is further divided into two strategies (Mueller-Dombois and Ellenberg, 1974; Grieg-Smith, 1983), which are divisive and agglomerative strategies. In a divisive strategy the population is progressively subdivided into groups of diminishing size, while in an agglomerative strategy, a hierarchy may be built up by fusing individuals progressively into groups of increasing size until the whole population is merged into a single group (Greig-Smith, 1983). Similarly, there is a choice between monothetic strategy, which is based on a single attribute and polythetic strategy, which is based on a number of attributes (Dingby and Kemptoon, 1994.

2.4.2. Ordination

Ordination produces groups from the concept that vegetation is continuous (the continuum concept). It does not produce distinct groups, which can be classified instead it shows the interrelationships among the groups that are to be controlled by environmental gradient (Kershaw, 1973). Ordination aims at representing the individuality of each stand. It enables to obtain information on both continuity and discontinuity of the data studied as well as to recognize the number of possible clusters and their shapes (Kershaw, 1973).

The success of ordination method depends on the use of appropriate variety of environmental variables (Begon *et al.*, 1996) and providing some hypothesis to be tested about the relationships between community composition and environmental factors (Chapman and Reis, 1992). Results obtained by ordination emphasizes the occurrences of predictable association of species under particular set of environmental variables and their common trend, which are most important in sorting out a group (Begon *et al.*, 1996).

In plant ecology, gradient analysis or ordination methods can help researchers to summarise plant community data, by providing an indication of the true nature of variation within the vegetation of the area under study, as well as enabling the distribution of individual species within different communities to be examined and compared (Kent & Coker, 1992). Gradient analyses also provide summaries of variation within sets of vegetation samples which can then be correlated with environmental controls to define environmental gradients (Kent & Coker, 1992). Gradient analysis and ordination techniques are a group of methods for data reduction and exploration leading to hypothesis generation. The methods are essentially descriptive and enable researchers to formulate ideas about the plant community structure as well as possible causal relationships between variation of vegetation and its environment (Kershaw, 1973; Kent & Coker, 1992).

Ordination is used by community ecologists, especially vegetation ecologists, to quantify and study patterns in plant communities. Ordination consists of a set of multivariate techniques which reduce the multiple variables in a community to a few dimensions which reflect the most important patterns in the data set (Gauch 1982; Digby & Kempton 1994). Ordination methods can be classified into constrained ordination and unconstrained ordination techniques.

In direct gradient analysis or constrained ordination, environmental factors are identified before the analysis. These factors are directly incorporated into the analyses (ter Braak, 1995), and hypotheses can be rigorously tested in an a priori manner (Legendre & Legendre, 1998). The method assumes that the underlying environmental gradients are known and are quite distinct (Kent & Coker, 1992; Burbour *et al.*, 1987). Constrained techniques are designed to directly investigate hypothesis about differences in characteristics of sites contributing to differences in species composition. An additional advantage of constrained ordination techniques is that a significance analysis can be done to investigate whether the observed patterns can be a chance-effect or not. The most commonly used DGA method is Canonical Correspondence Analysis (ter Braak, 1995).

Unconstrained or indirect gradient analysis is a term applied to techniques which operate on a set of vegetation data by examining the variation within it. These ordinations are based on analysis of floristic data independently of any preconceived notions of controlling environmental factors (Kent & Coker, 1992). A second set of analysis is then performed once the major sources of variation in the vegetation data have been described and summarised (ter Braak, 1986).

2.4.3. Species Diversity, Richness, Evenness and Similarity

Biodiversity refers to the variety of life forms, the genetic and species diversity they contain, and the assemblage they form. Biodiversity is often measured in terms of species diversity. Paul (1993) noted that species diversity could be viewed in terms of species richness, species endemism, evenness and taxonomic diversity. Measures of diversity are frequently seen as indicators of the normal functioning of ecological systems. The presence of a great number of species with different structures, different chemical composition, and different life spans form one of the most important bases of life for humans throughout our planet (Reaka-Kudla *et al.*, 1997). One important reason for studying and measuring diversity will be to measure the impact of projects or interventions that were planned to achieve landscape domestication.

Species diversity is a characteristic unique to community level of biological organization. Higher species diversity is generally thought to indicate a more complex and healthier community because a greater variety of species allows for more species interaction, hence greater system stability, and indicates good environmental conditions. Community is said to have high species diversity if many nearly equally abundant species are present. If community has only a few species or if only a few species are very abundant, then species diversity is low (Brower *et al.*, 1984).

The description of plant community involves the analysis of species diversity, evenness and similarity. Diversity and equitability of species in a given plant community are used to interpret the relative variation between and within the community and help to explain the underlying reason for such a difference. The two main factors taken into account when measuring diversity are richness and evenness. Richness is a measure of the number of different species in a given site and can be expressed in a mathematical index to compare diversity between sites (Zerihun Woldu, 1985). Species richness refers to the total number of species in a community whereas evenness is the relative abundance of species within the sample or community making up the richness of an area (Kent and Cooker, 1992; Krebs, 1999). Species richness index is of great importance in assessing taxonomic and ecological values of habitats. Species richness is broadly used as a measure of biodiversity with various objectives such as monitoring biodiversity in order to prioritize management or conservation actions or design ecological indicators.

Evenness is a measure of how evenly the cover within a plot is distributed between species. Evenness values range from 0 to 1. An evenness value of 1 indicates that plant cover within a plot is evenly shared among the species present (e.g. only one species is present, two species both account for 50% of the cover, etc.). A low evenness value indicates that one or a few plants account for the majority of the cover, whereas other plants cover very little of the plot.

Ecologists have devised a huge range of indices for measuring diversity, each of which seeks to express the diversity of a sample or quadrat by a single number. Given the large number of indices, it is often difficult to decide the best method of measuring diversity. One good way to get a better diversity measures is to test their performance with data. A rather more scientific method of selecting a diversity index is on the basis of whether it fulfils certain functions criteria, its ability to discriminate between sites, dependence on sample size, what component of diversity is being measured, and whether the index is widely used and understood (Clarke and Warwick, 2001). Of the various indices, Shannon Weiner diversity is the most frequently used index for comparing diversity between various habitats (Heuserr, 1998; Magurran, 1988; Grieg-Smith, 1983; Clarke and Warwick, 2001). Shannon Wiener diversity index that combines richness and evenness naturally varies between 1.5 and 3.5 and rarely exceeds 4.5 (Kent and Cooker, 1992).

Species diversity could be viewed from different approaches in terms of alpha, beta and gamma diversity (Rosenzweig, 1995). Alpha diversity (α) refers to the diversity of species within a particular habitat or community. Beta diversity (β) is a measure of the rate and extent of change in species along a gradient from one habitat to another. It is between habitat diversity that measures turnover rates. Beta diversity is sometimes called habitat diversity (Kent and Cooker, 1992). Gamma diversity (γ) on the other hand is the diversity of species in comparable habitats along geographical gradients and is independent of the two (Kent and Cooker, 1992).Similarity index measures the degree to which the species composition of the quadrats/samples is a like, whereas dissimilarity coefficient assesses which two samples or quadrats differ in composition. It can be used to assess the similarity between different habitats with reference to the composition of species.

Jaccard and Sorensen are the most common binary similarity coefficient, because they rely on probability data, except that Sorensen gives more weight to the species that are present in both quadrats and therefore less weight to species that are present in only one quadrat (Kent and Cooker, 1992). Patterns of plant species diversity have often been noted for prioritizing conservation activities because they reflect the underlying ecological processes that are important for management (Kent and Cooker, 1992).

2.4.4. Sample Based Rarefaction Curve

Exhaustive biodiversity surveys are nearly always impractical or impossible (Lawton *et al.*, 1998), and the difficulties inherent in estimating and comparing species richness from sampling data are well known to ecologists and conservation biologists (Chazdon *et al.*, 1999). Species richness usually increases with sample size and differences in richness actually may be caused by differences in sample size. The comparison of species richness of two communities may be biased if the sampling effort strongly differs. For that reason, Gotelli and Colwell (2011) recommend that species richness of the community surveyed using the largest number of sampling units be rescaled to be comparable to the data set describing the second community with the smallest number of sampling units. The principal use of rarefaction curves has long been the comparison of species richness among empirical samples that differ in the total number of individuals (Lee *et al.*, 2007; Sanders, 1968) or among sample-based datasets that differ in the total number of sampling units (Longino and Colwell, 2011; Norden *et al.*, 2009).

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Description of Study Areas

3.1.1. Lake Abaya and Lake Chamo Wetlands

3.1.1.1. Topography and Location

Lakes Abaya and Chamo are part of the Ethiopian Rift Valley Lakes (Abaya-Chamo basin) bounded by eastern and western escarpments in SNNPRS (Figures 3.1 and 3.2). Lake Abaya is the largest lake in the Ethiopian Rift, located between 5°3'19"N and 6°45'11"N latitude and 37°18'55"E and 38°7'55"E longitude (EMA, 1988). It has a maximum length of 79.2 km, maximum width of 27.1 km with a surface area of 2600 km^2 (Seleshi Bekele, 2001). It has a maximum depth of 24.5 m and is located at an average altitude of 1,235 m.a.s.l. (Seleshi Bekele, 2001).

Figure 3.1: Map of Ethiopia showing location of the study areas (Lake Abaya and Lake Chamo wetlands)

the top of the mountain (Mengistu Negash *et al.*, 1989; Thiemann, 2006). Based on the 10 years climate data (2001-1010) from Arba Minch meteorological station, the average annual temperature is 24°C where as mean annual rainfall is 933 mm. The rainy seasons of the study area are from September to October and March to June, with mean minimum monthly rainfall in January and maximum in April. Hot and dry weather is predominant from December to February. The mean minimum temperature of the coldest month and the mean daily maximum temperature of the warmest month is 15.8°C and 33.4°C, respectively.

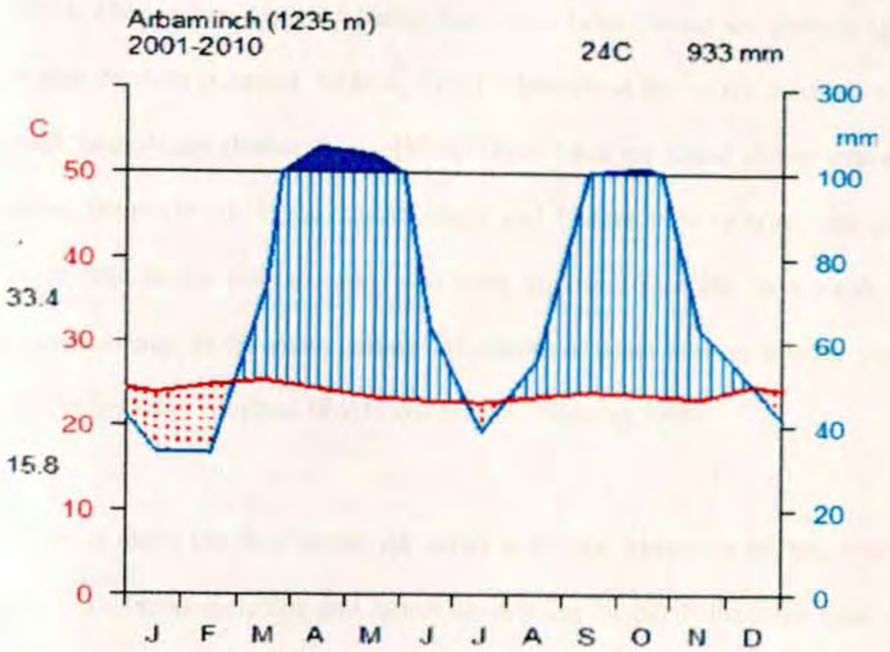


Figure 3.3: Climate diagram for Lakes Abaya and Chamo wetlands (Source: EMSA, Ethiopian Meteorological Service Agency, 2012). The diagrams start with January in the left corner of the diagram. 20 mm of monthly precipitation (right ordinate) equal 10°C average temperature (left ordinate). The dotted area in between the precipitation curve (blue) and the temperature curve (red) indicate dry season. Vertical lines inside the precipitation curve indicate moist season. The shaded area inside the precipitation curve indicates frost periods. Each tic mark along the horizontal line (abscissa, x-axis) indicates a month. Numbers to the left of the diagram show mean daily maximum temperature of the warmest month and mean daily minimum temperature of the coldest month. The length of the observation period for temperature and precipitation respectively for the station (Arba Minch) located at 1235 m.a.sl. is given in the top left corner of the diagram. Numbers in the top right corner of the diagram show annual average of temperature and annual precipitation sum for the station.

3.1.1.3. Geology and Soils

The Abaya and Chamo lakes and associated wetlands being part of the rift valley were formed by volcanic activities in the Rift Valley during the period of Pliocene and Holocene. Late Pliocene-Quaternary volcanism is mainly localised in the rift floor (Morton *et al.*, 1979). However, the rift valley basin is dominated by young volcanic and sedimentary rocks (Miocene to Recent), which lies within old (Precambrian) shield rocks (McConnel, 1972). The rift valley floor near Lakes Abaya and Chamo is filled with alluvial sediments (Mohr, 1971). The western edges of Lakes Abaya and Lake Chamo are covered by lacustrine and swamp deposits (Chernet Tesfaye, 1982). Throughout the valley there are extensive north–south fault Zones (Baker *et al.*, 1972). These lakes are found in less intensely faulted rift valley floors (Mohr, 1971). Lakes Abaya and Chamo were enlarged and united to form a single lake in the pluvial period and were separated probably as a result of inter-pluvial climatic change or the down cutting and change of water level as it is the case in the central Rift Valley lakes (Zerihun Woldu and Mesfin Taddesse, 1990).

The soils along the floor of the rift valley and Lake Abaya are alluvial type (Vukasinovic, 1969). Colluvial materials and lacustrine deposits of the Pleistocene were common when Lake Abaya retreated (Mohr, 1971; Thiemann (2006). Therefore, the soils of the area around the floor of the rift valley and Lake Abaya can be categorized as Fluvisols of the FAO/UNESCO revised legend (1990).

In the shore lines of southern and western part of the lake Chamo is mainly covered by fluvisols, which are very fertile and developed from Kulfo and Sile rivers and lacustrine deposits (NAE, 1988). These soils are intensively used soils for agricultural practices. The Eastern side of Lake Chamo is mainly covered by luvisols which have good agricultural potential (NAE, 1988). Some areas in the North Western part and southern part of Lake Chamo are covered by Dystric Nitosols in the basin (NAE, 1988).

3.1.1.4. Major Land Uses and Land Cover

Lake Abaya-Chamo basin is covered by different vegetation types and experiences different land use practices. The freshwater swamps at the mouth of the Kulfo River and in Lake Chamo are dominated by *Typha angustifolia*, tall waterside grasses and leguminous trees, such as *Aeschynomene elaphroxylon* and *Sesbania sesban*. Taller trees found in the wetlands include *Ficus Vasta, Acacia tortilis* and *Balanites aegyptiaca*. The forest between the two lakes is dominated by *Ficus sycomorus* which can grow up to 30 m tall. The shorelines in the northern, western and southern parts of the lakes are covered by grasses, sedges, and scattered trees. Almost all of the wetlands associated with the two lakes are located in this strip of plain land. This strip of plain land is also densely populated and intensive agriculture is practiced.

The land use of Lake Abaya and Chamo wetlands, especially western side of the two lakes, has been changed rapidly due to extensive deforestation as a result of increased number of population in the area (Seleshi Bekele, 2001). The extensive deforestation resulted in the replacement of vegetation cover by cultivated lands. Farming activities like livestock rearing and crop production are the main land use practices in the catchment surrounding the lakes. Extensive areas to the west of Lake Abaya were cleared in the 1960s and 1970s to establish large-scale mechanized farms for cotton and other crops (Zerihun Woldu and Kumlachew Yeshitila, 2003). Cotton and banana are the dominant crops. State farms like Bilate, Arba-Minch and Sile (recently given for private investors) are examples of intensive farming in the plain land adjacent to the lakes (EMA, 1988; NAE, 1988). In the Lakes Basin the intermediate zone between the humid highlands and semi arid low lands are covered by bushland and scrublands. This type of vegetation also covers the southern, western and northern part of the lakes. Very dense ground water forest with a number of bubbling streams or watersprings covers the shoreline in the northern part of Lake Chamo and southern part of Lake Abaya. It was the main source of wood for Arba Minch town. The increase in the demand for wood for charcoal, fire wood and construction materials has highly affected the land cover in recent years. As deforestation of the natural vegetation continues, soil loss due to erosion may lead to an increase in sediment load of the lakes (Seleshi Bekele, 2001).

3.1.1.5. Population and Socio-Economic Conditions

The current growth rate of population in the two Rift Valley Lakes is very high and has an adverse effect upon development in the basin (SNNPRS Population Bureau report, 2004). As population number increases in the two Lakes Basin, pressure on the land to expand farming activities also increases leading to deforestation and consequently to uncontrolled erosion during heavy rains. Though highlands of the basin have been settled for a long period in history, the lowlands adjacent to the lakes have been settled in recent times mainly by the people who came from highlands forced to migrate with the increase in population number. Farming activities like cattle rearing and crop production were the main source of livelihoods. In recent times, fishing in Lake Chamo is the main economic activity.

3.1.2. Fincha'a-Chomen Marsh

3.1.2.1. Topography and Location

Fincha'a-Chomen Marsh is found in Oromia Regional State in Horo Guduru Wollega Zone (previously under East Wollega Zone) and is found at about 280 km west of Addis Ababa. It is located at 09°34'N and 37°21'E at an average elevation of 2,222 m (EMA, 1988) with a surface area of about 60,000 ha.

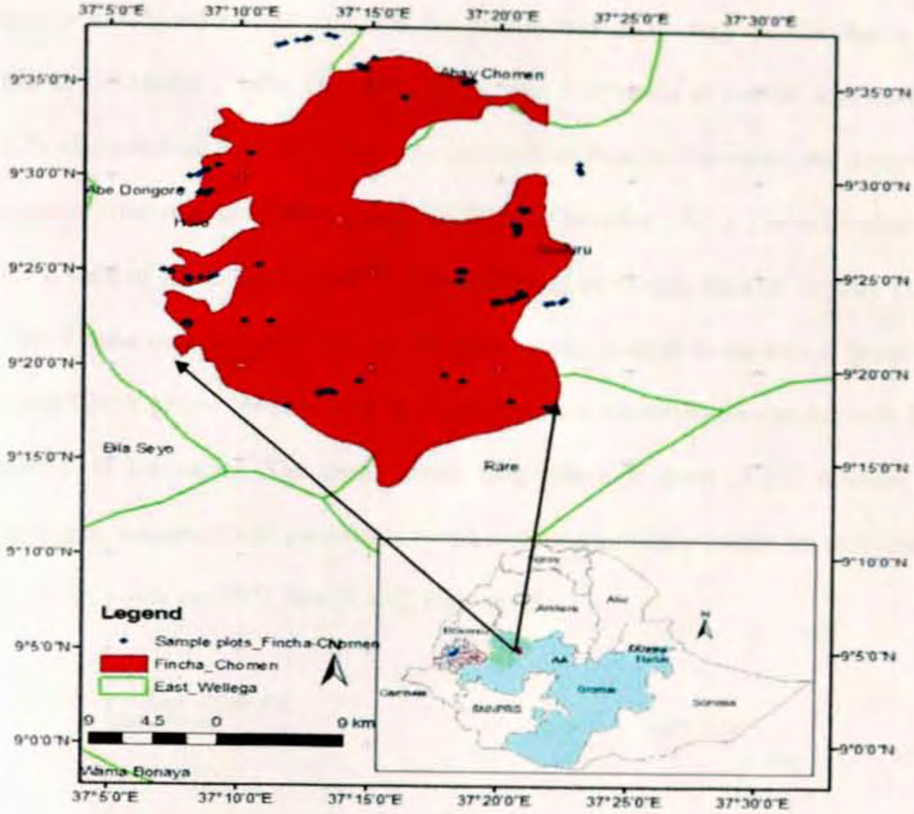


Figure 3.4: Map of Ethiopia showing location of the study area (Fincha'a-Chomen).

3.1.2.2. Geology and Soils

The geology of Ethiopia falls within the geological structural units of the Horn of Africa (Mohr, 1971). Precambrian rocks form the basement rock of the south-western plateau overlying by tertiary basal traps lava flow which are generally flat (Mohr, 1971). In South-western Ethiopia, soils are deep and belong to the Order Oxisols (Mohr, 1971). The soils in Fincha'a Valley are made of alluvial and colluvial materials from the surrounding escarpments.

3.1.2.3 Climate

The western region of Ethiopia is characterized by contiguously distributed rainy months and evenly distributed rainfall and it is the wettest with eight rainy months that extend from March to October (Daniel Gamachu, 1977). The distribution of rainfall is unimodal (Figure 3.3); characterized by a prolonged wet season from June to September and a short dry spell showers from middle of March to April (Daniel Gamachu, 1977). The rainy season starts at the middle of March and it ends in October. Based on climate data of 10 years (2001-1010) from Fincha meteorological station, the mean annual rainfall in the area is about 1650 mm, rainfall peak period between May to September, and decreasing in October with little or no rainfall in November. The mean annual temperature is about 18.2°C whereas the mean minimum temperature of the coldest month and the mean daily maximum temperature of the warmest month are 9.5°C and 28.4°C, respectively.

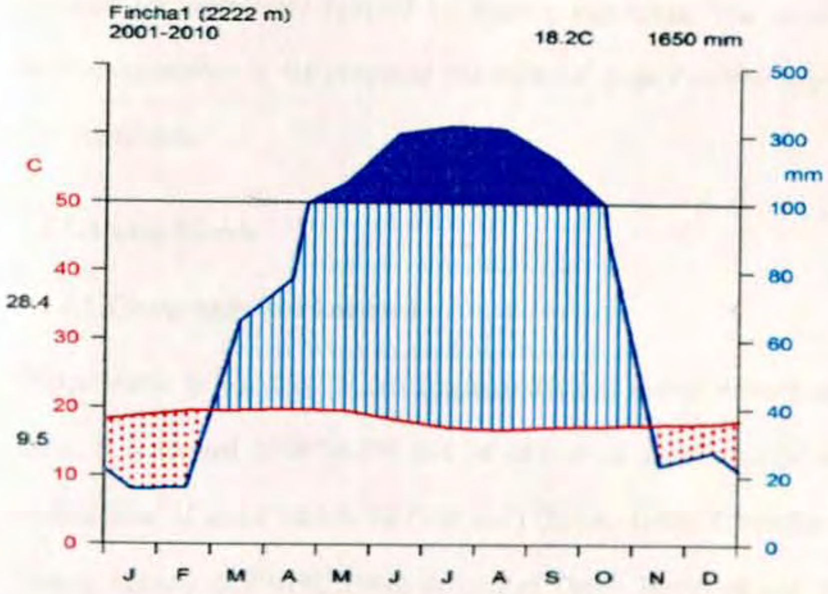


Figure 3.5: Climate diagram for Fincha'a-Chomen wetlands Source: EMSA (Ethiopian Meteorological Service Agency, 2012). The climate diagram was interpreted in the same manner as figure 3.3.

3.1.2.4 Major Land Uses and Land Cover

Based on the information obtained from the Horo Woreda and Rural Development Office, potential arable land accounts for about 45.27%, pasture or grazing land 6.11%, while 30.41% is forest land, 15.08% is swampy and marshy, 0.68% degraded or barren land and 2.45% is construction and other land types. Major crops produced in this District are cereals under private farmer holdings. Niger seed (NUG) is an important local cash crop. According to reports from HWRDO (2009), land cover under different crop production increased from 21,295 ha (1998) to 21,642,825 ha (2000) indicating that there is high demand for more land including wetlands for agricultural practices. Deforestation and loss of fertility due to expansion of agricultural land and increased population size are some of the major problems in this area (HWRDO, 2009; Woldeyohannes Enkossa, 2008). Vegetation coverage of the District includes marshlands, grasslands, forests, bushslands and shrubs. Fincha'a-Chomen marshes are extensively covered by floating vegetation. The most important species in floating vegetation is the perennial stoloniferous grass *Panicum hygrocharis*, which forms floating islands.

3.1.3. Dabus Marsh

3.1.3.1 Topography and Location

Dabus Marsh is found in Oromia Regional State in central western parts of West Wollega Zone. It is located at 09°16.2'N and 34°48'E at an average elevation of 1,300 m with a surface area of about 70,000 ha (700 km^2) (EMA, 1988). Ethiopian Wildlife and Natural History Society (EWNHS, 1996) designated Dabus Marsh as one of the Important Bird Areas. Dabus River is an important tributary draining the relatively wet southeast region of the Abay Basin. According to Sutcliffe (2009) and MoARD (2005), Dabus and Didessa rivers together contribute a third of the total flow in the Abay Blue Nile Basin.

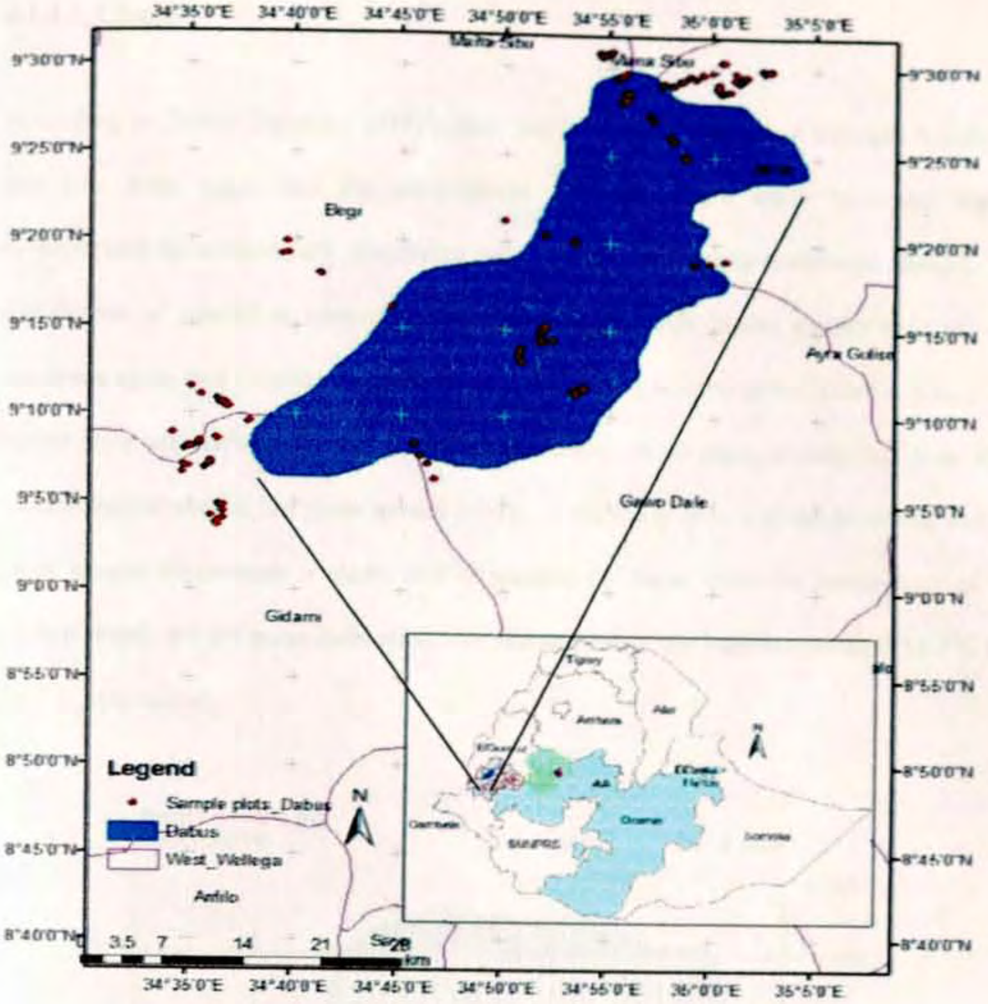


Figure 3.6: Map of Ethiopia showing location of the study area (Dabus wetland).

3.1.3.2. Geology and Soils

The occurrences of geologic elements in the West Wollega (or Wollega Province) are the results of Precambrian and Cenozoic era (Mohr, 1971). The tertiary basaltic rocks account for the majority of high land rock cover of West Wollega (Mohr, 1971). Dystric Nitosols form the major group of soil units occurring in most parts of the Zone.

3.1.3.3. Climate

According to Daniel Gamachu (1977), there are 14 rainfall regimes in Ethiopia which fall into two main types, and the southwestern highlands come under type one that is characterized by contiguously distributed rainy months and evenly distributed rainfall. The distribution of rainfall is unimodal type (Figure 3.4) which begins usually in April and continues up to mid October and is uniformly distributed in most years. There is a long dry period from mid October to the end of March. Based on 10 years climate data from Begi metereological station, the mean annual rainfall in the study area is about 1415 mm and the mean annual temperature is about 19.8°C whereas the mean minimum temperature of the coldest month and the mean daily maximum temperature of the warmest month is 11.8°C and 30.9°C, respectively.

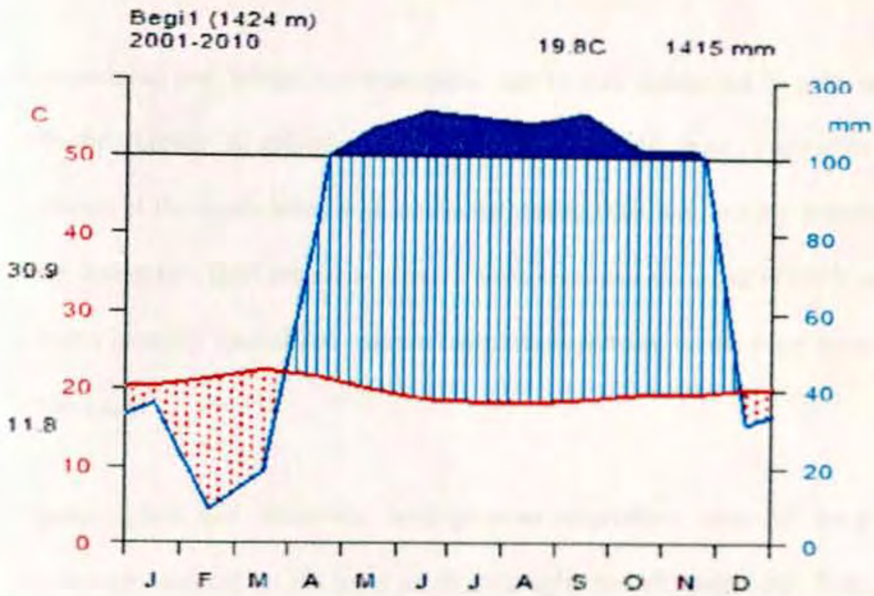


Figure 3.7: Climate diagram for Dabus wetlands (Sources: EMSA, Ethiopian Meteorological Service Agency, 2012). The climate diagram was interpreted in the same manner as figure 3.3

3.1.3.4. Population and vegetation types

According to the 2007 Population and Housing Census report, the total population of West Wollega Zone was 1,351,979. Agriculture is characterized by mixed cropping practices mainly coffee, maize, tef, sorghum, barely, wheat and noug (GWSPMFRDA, 2004). The forest patches are found mostly in limited areas in the eastern and northeastern parts, grassland occupy western, northwestern, southwestern, central and southern and swamps and marshes occur in the central western part of the Zone. Broad leafed forest, grasslands and wetland (marshes and swamps) are the common types of climatic climax vegetation of West Wollega (GWSPMFRDA, 2004).

3.2. Data Collection

3.2.1. Vegetation Data Collection

A vegetation and habitat reconnaissance survey was conducted in each of the study areas with the purpose of getting acquaitance with the study areas. Vegetation sampling in the wetlands of the study areas was conducted during both wet and dry seasons. Sampling was done during two field season as a much more extensive sampling effort is necessary in order to better quantify spatial and temporal vegetation patterns across these diverse ecosystems or landscapes.

Representative and relatively homogeneous vegetation units of sampling sites were purposively selected on the basis of physiography and physiognomy. Transects were set up preferentially across area where there were rapid changes in vegetation or marked environmental gradients (Muller-Dombois and Ellenberg, 1974). Transects were laid out across the study sites (Muller-Dombois and Ellenberg, 1974) and selected to represent hydrological variations and habitat heterogeneity. The number of transects varied depending on the size of wetland and the habitat variation observed. Transects were started from about the middle (in palustrine wetland), at the edge of the open (in lacustrine wetlands) and in perpendicular to flowing water (in reverine wetland) and extended to the ecotone along the edge on both sides of the wetland. Transect sampling is considered by many field scientists to be advantageous in that it has the potential to show progressive changes along a landscape segment, and thus the researcher may rapidly establish the local stratigraphic and geomorphic relations (Daniels and Hammer, 1992).

Mueller-Dombois and Ellenberg (1974) and Kent and Coker (1992) suggested quadrat size for meadow and fen vegetation type is 4 m x 4 m (16 m^2) and a shrubby heath, tall herbs with grassland vegetation type is 8 m x 8 m (64 m^2). Thus, because of differences in vegetation zonation pattern and continuity of substrates, vegetation data were collected at each site using a plot size that meets the minimum area requirements for meadow, shrubby heaths, tall herbs with grassland vegetation and shrubby swamps. The plots were not nested but different plots sizes were used in different vegetation units. Sample plots were placed along transects in each of the purposively (preferentially) selected habitat units or strata based on moisture gradient and dominant vegetation types. Location of the plots was chosen visually and purposively to ensure that it gives a representative view of the plant species and abundance in that unit. The location of each plot was recorded using a GPS.

Within each sample plot in all study areas, all plant species were recorded and the percentage aerial cover of each species was estimated. This was later converted to 1-9 scale following the Braun-Blanquette method modified by Van der Maarel (1979) as floows:

- 1: Rare, generally one individual;
- 2: Occasional, with less than 5% cover of the total;

- 3: Abundant, with less than 5% cover of the total;
- 4: Very abundant, with less than 5% cover of the total;
- 5: 5-12% covers of the total area;
- 6: 12.5-25% cover of the total area;
- 7: 25.5-50% cover of the total area;
- 8: 50.5-75% cover of the total area;
- 9: 75-100% covers of the total area;

Cover was estimated as the percentage of sampling area covered by the vertical projection of individuals of each species present (Mueller-Dombois & Ellenberg, 1974). Plant species occurring outside the plots were also collected and identified to produce a comprehensive list of the plant species diversity of the study area. Voucher specimens were collected, coded, pressed and dried for subsequent identification and verification at the National Herbarium (ETH), Addis Ababa University, using Flora of Ethiopia and Eritrea and those of other neighbouring countries. The plant specimens collected were identified to the family, genus, and species level.

3.2.2. Environmental data collection

The following environmental variables were recorded in each plot at different levels of detail: drainage, hydrogeomorphology, disturbance, slope and elevation (Appendix 2). At each site (sample plot), estimate of disturbance intensity was recorded based on physical evidence of the site characterestics (e.g. soil irregularities, burning, defoliation and dung present). Plot level hydrogeomorphologic features were rated based on physical evidence of the site or sample plot (e.g., position of the land scape and additional water source) where as drainage was recorded based on water holding capacity of the soil or level of saturation. Depth to water table was measured in each plot with a labelled PVC pipe. Environmental data on topographic parameters such as altitude and coordinates for each plot were determined with GPS. Photographs were taken for visual representation of the vegetation and other site characteristics (Appendices 5, 6 and 7). It would have been desirable to investigate a wider range of environmental parameters such as soil nutrients and water chemistry, but this was constrained by the problem of transporting equipment and other limited resources.

3.3. Data Analysis

Although vegetation sampling was conducted during wet and dry periods, environmental data intended for determining factors influencing the plant community types was collected only during wet season. Thus, classification and ordination analysis for description of the vegetation (plant community types) and for determining factors influencing the vegetation composition included samples only from the wet season data. Dry season vegetation data was employed to ivestigate if there was seasonal shift in floristic composition and taxonomic diversity. Clustering was done from the dry season vegetation data to show the changes in number of plant community types.

3.3.1. Vegetation and Environmental Data Analysis

Multivariate data analysis methods were used to analyze the vegetation and environmental data. Statistical analysis was performed in the R version 2.14 statistical computing program (R Development Core Team, 2009) using packages for classification and ordination. Programs for ecological and environmental data analysis by Zerihun Woldu (2012) were employed. In vegetation ecology, many studies have pointed out that among the multivariate approaches ordination and classification are the two main methods. The choice of the method to be used depends on the ecological question to be answered (Gauch and Whittaker, 1972; Gauch, 1982). It is now generally accepted that the choice between the two methods depends on the objectives of the data analysis and the structure of the data set being examined, rather than on preconception about the nature of the vegetation (Grieg-Smith, 1997) and there is no prior reason to accept either a classification or an ordination as an inherently correct technique (Anderson, 1984). Bearing this in mind, both ordination and classification techniques were employed to study the ecology of wetland vegetation.

Vegetation data were analyzed using agglomerative hierarchical cluster analysis (Westbrook, 2005) using similarity ratio as a resemblance index and Ward's linkage method to identify vegetation assemblages. Cluster analysis is a useful way of identifying groups when working with ecological data and has been used for many years in community ecology (McCune and Grace, 2002). Agglomerative clustering starts with the points as individual clusters and iteratively reduces the number of clusters by merging the two most similar objects or clusters, respectively, until only one cluster is remaining. Similarity ratio is one of the similarity indices which measure the similarity or disimilarity between vegetation samples or quadrats. The choice of a distance measure is an ecological, not a statistical decision. Ward's linkage method is distinct from all other methods because it uses analysis of a variance approach to evaluate the distances between clusters. This method attempts to eliminate the differences in total abundance among sample units. In addition, the Ward's method minimizes the total within group mean of squares or residual sum of squares (van Tongeren, 1995; McCune and Grace, 2002). In general, this method is regarded as very efficient and tends to create equally sized clusters of small size.

Distinct clusters were identified at appropriate hierarchical levels and the quadrats of the data set were then arranged using the sequence of the quadrats in the dendrogram produced. The mean cover value of each species in each cluster identified was calculated and a synoptic table was produced. The species with highest mean cover value was used to determine dominance and sub-dominance of species in cluster groups. Based on the cluster analysis output and the resulting synoptic table and ecological evaluation in the field, the number of community types (clusters) was determined at appropriate dissimilarity levels (height of the dendrogram). The plant community types were named after one, two or three dominant species, using the highest mean cover values of plant species which occur in each group. Dominant species are those that are most conspicuous in the community and are high in one or more of the importance values (Whittaker, 1975), mean cover value in this case. The identified plant community types or groups were tested for the null hypothesis of no significant difference between the groups using the Multi-response Permutation Procedures (MRPP) (ter Braak and Šmilauer, 2000 and 2002; Ludwig and Reynolds, 1988). A significance level of 0.05 was used to determine if the compositional differences between groups were statistically significant. MRPP is a nonparametric procedure that is useful for testing for significant differences between two or more groups. It is an appropriate method to use with ecological community data that often do not meet distributional assumptions required of parametric tests that address similar questions (McCune and Grace, 2002). The Plant community types were examined using non-metric multidimensional scaling (NMDS) ordination. NMDS was chosen because the tests can produce robust visualizations of data despite numerous zero-values and highly variable data with lack of normality (McCune and Grace 2002). Using the synoptic table and the habitat information gathered during the sampling period, the different plant communities were described.

Canonical Correspondence Analysis (CCA) (ter Braak, 1987, 1988 and 1990; Hill, 1979) was used for revealing patterns in the species composition data and relating the patterns to measured environmental variables. Canonical ordination is a class of techniques for relating the composition of plant communities directly to their environment (ter Braak, 1988). CCA ordination technique assumes a unimodal distribution of species in relation to environmental variables (McCune and Grace, 2002; McCune and Mefford, 1997). Species cover abundance data for each plot together with the corresponding plot versus environmental variables data matrix were subject to Canonical Correspondence Analysis (CCA) to reveal the relations between the species composition and environmental variables.

The environmental data to be included in the CCA were determined using stepwise backward and forward selection of variables by ANOVA test. The CCA generated biplot scores (i.e., correlations between environmental variables and ordination axes) were used to infer the relative importance of each environmental variable for prediction of species composition and distribution (ter Braak, 1995). The vegetation samples were plotted in an ordination diagram with the environmental variables shown by vectors (arrows), while plots by points. The length of the arrows is proportional to their importance and the directions of the arrows show their correlation with the axes.

3.3.2. Diversity Analysis

Statistical measurement regarding species diversity, richness and evenness of the plant community types was carried out by using Shannon-Wiener (1949) diversity index. The Shannon diversity index (H') was computed using the mean cover values of the species in the plant community types as the input matrix (synopsis output). The Shannon diversity index is calculated by using the formula:

Shannon diversity index $H' = -\sum_{i=1}^{s} P_i \ln P_i$ Where s= the number of species; P_i = the proportion of the individuals of the ith species or the abundance of the ith species expressed as a proportion of total cover; Ln= log base$_n$ (natural logarithm)

Equitability which determines the relative evenness of the species within the plant community was also calculated. Evenness is a measure of how evenly the cover within a plot is distributed between species. Evenness values range from 0 to 1 with 1 being complete evenness (Kent and Cooker, 1992). An evenness value of 1 indicates that plant cover within a plot is evenly shared among the species present. The higher the value of evenness index, the more even the species is in their distribution within the given area. A low evenness value indicates that one or a few plants account for the majority of the cover, whereas other plants cover very little of the plot. Equitability (Shannon evenness, J) is calculated by the following formula:

Evenness index $J = \frac{H'}{H'max} = \frac{-\sum_{i=1}^{s} Pi \ln Pi}{LnS}$ Where, J = the equitability; LnS= log base$_n$; S = the number of species

Floristic similarities with regard to species composition among and between study sites were calculated by employing Sorenson's similarity coefficient (Kent and Coker, 1992) by using the equation: $S_C = 2a/(2a + b + c)$ Where S_C = Sorenson's similarity coefficient; a = number of species common to both categories; b = number of species present in the first category and absent in the second and c = number of species present in the second category and absent in the first.

Alpha diversity refers to the diversity within a particular area or ecosystem, and is usually expressed by the number of species (species richness) in that ecosystem. Beta diversity, a measure of the extent to which the diversity of two or more spatial units differs, was determined through Whittaker's (1972) method. Beta diversity is a measure of the total number of species that are unique to each of the ecosystems being compared. Whittaker's idea was that the total species diversity in a landscape (γ) is determined by two different things, the mean species diversity in sites or habitats at a more local scale (α) and the differentiation among those habitats (β).

$\beta_w = S_c/S_{ave} - 1$ Where β_w = Whittaker's Beta diversity; S_c = the no of species in composite sample Save = the average species richness in the entire set.

3.3.3. Rarefying Species Richness

To compare species richness across sites of different sizes, sample-based rarefaction curves were computed for each site in the program EstimateS (Colwell, 2005) and compared expected species richness in the area sampled at the smallest number of plots. Rarefaction involves constructing a smooth species accumulation curve by randomly resampling the data, and then comparing species richness across all sites at the point on the curve corresponding to the number of individuals (samples) at the site with the lowest sampling intensity.

CHAPTER FOUR

4. RESULTS

4.1. Wetlands of Lake Chamo

4.1.1. Floristic Composition

Eighty eight species of plants were recorded from wetlands of Lake Chamo (Appendix 1b). The specimens identified belong to 69 genera and 31 families. Only five families account about 63.7% of the total proportion (Figure 4.1). The families with the greatest representation were Poaceae with 17 species (19.3%) in 15 genera and Asteraceae with 16 species (18.2%) in 14 genera. Other common families after Asteraceae were Fabaceae with 13 species (14.8%) in 8 genera, Cyperaceae and Malvaceae (each represented by 5 species, 5.7%), while the rest 26 families comprised 36.4% of the total species encountered (Figure 4.1). Amaranthaceae was represented by 3 species. The families Lamiaceae, Asclepiadaceae, Convolvulaceae, Euphorbiaceae and Nymphaeaceae were represented by 2 species each. The remaining families were represented by one species belonging to single genus each.

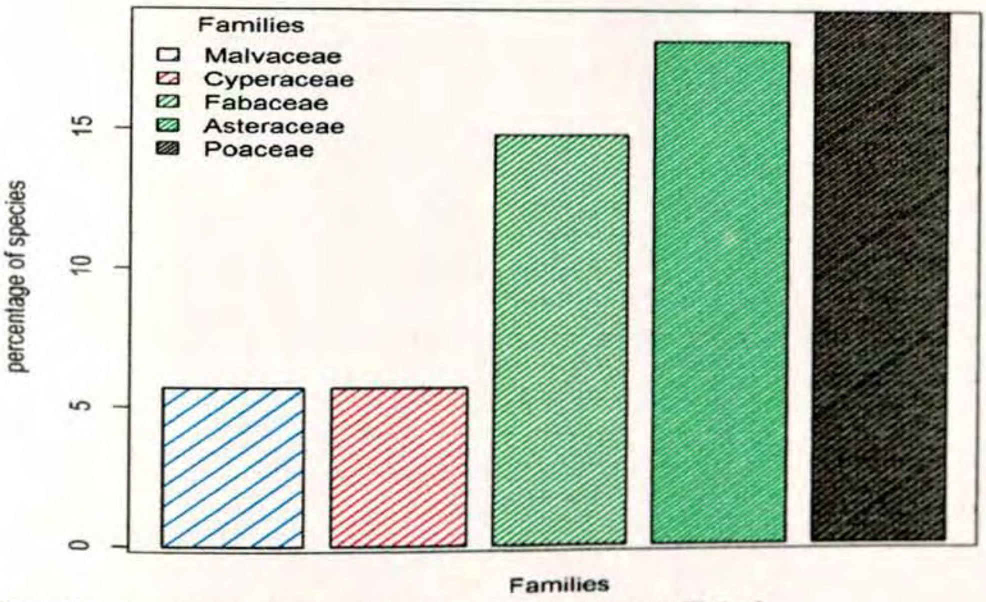


Figure 4.1: Families with the greatest representation in Lake Chamo Wetland.

4.1.2. Description of Plant Community Types of Lake Chamo Wetlands

Based on the cluster analysis output (Figure 4.2), the resulting synoptic table (Table 4.1) and ecological evaluation in the field, four plant community types (clusters) were identified between 1.5 to 2.0 heights (0.45 - 0.60 dissimilarity levels) of the dendrogram. The plant community types were named after one or two dominant species, using the highest mean cover values of plant species which occur in each group (Table 4.1). Communities with their dominant and sub-dominant species, the number of relevés they contained and diversity index were given in table 4.2. The most common herbaceous species based on mean cover values include *Cynodon aethiopicus, Cyperus articulatus, Cyperus latifolius, Ipomoea aquatica, Leersia hexandra* and *Leptochloa fusca.* The highest mean covers in this study site were recorded for *Cynodon aethiopicus* and *Cyperus articulatus.* Species such as *Cynodon aethiopicus*, *Cyperus articulatus, Leersia hexandra, Sesbania sesban, Solanum incanum, Typha angustifolia, Cyperus latifolius* and *Aeschynomene elaphroxylon* were frequently distributed. Each of these species occurred in more than 15% of the total quadrats.

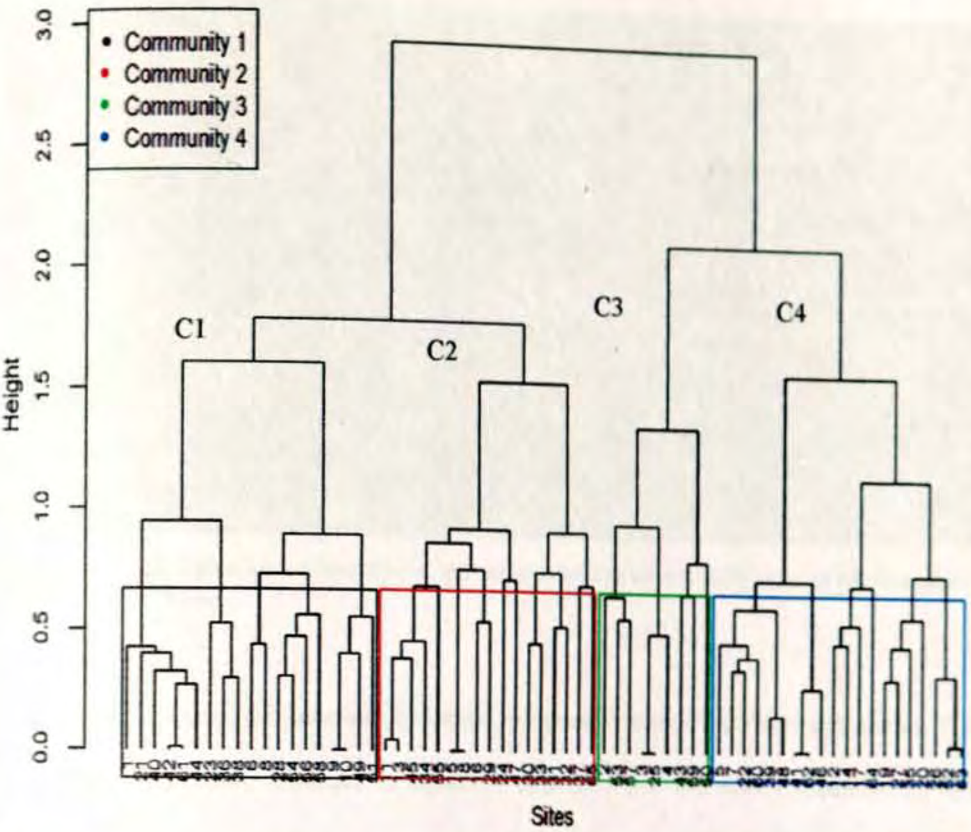


Figure 4.2: Dendrogram showing a hierarchical clustering of plant community types of Lake Chamo wetland vegetation.

Each plant community type is described below.

1. *Cynodon aethiopicus-Cyperus articulatus* community type: This community type was dominated by *Cynodon aethiopicus* and *Cyperus articulatus* (Figure 4.3). In terms of mean cover values, *Cyperus latifolius, Sesbania sesban, Ipomoea aquatica* and *Leptochloa fusca* were also important species. This community type consisted of 29% of the stands most which were sampled from west and southwest side of the lakeshore. Almost all of the plants in this community type were emergent macrophytes except *Nymphaea lotus* which is a floating-leaf plant. The vegetation composition of this community type was dominated by grass and sedge but small dense clusters of shrubs and trees were widely scattered throughout, creating a mosaic or zoned pattern.

Figure 4.3: The *Cynodon aethiopicus-Cyperus articulatus* community type in southwestern side of Lake Chamo

2. *Cynodon aethiopicus-Solanum incanum* community type: The dominant species of this community type were *Cynodon aethiopicus* and *Solanum incanum* (Appendix 5). Other associated species contributing most to the similarity of this community type were *Aeschynomene elaphroxylon, Lantana camara* and *Cyperus latifolius*. This grass dominated community occurred in areas adjacent to terrestrial vegetation on relatively dry soil condition. This ccommunity consists of 26% of the stands which were from north, northwest, west, and south of the lake shores. All of the plants in this community type were emergent macrophytes except *Nymphaea lotus*. This marginal vegetation type included a range of terrestrial plant species that occurred on elevated land within the wetlands.

3. *Leersia hexandra* community type: *Leersia hexandra* plant community type was the most common in the study area (Appendix 5). *Leersia hexandra* was the most dominant species with companions like *Solanum incanum. Hypoestes triflora, Achyranthes aspera, Leptadenia hastata, Pluchea ovalis* and *Rubus steudneri*. This grass dominated community comprised plots that were sampled from the south, southwest and southeast of the lakeshore. No submerged and floating species were recorded in this community type.

4. *Cyperus articulatus-Typha angustifolia* community type: This was dominated by *Cyperus articulatus* and *Typha angustifolia* (Figure 4.4). The sub-dominant species in this community type included *Leersia hexandra, Sesbania sesban* and *Echinochloa pyramidalis*. This community type consists of emergent species which were found in areas that have shallow, intermediate standing water for prolonged duration. It also consists of submerged (*Potamogeton pucillus*) and floating species (*Nymphaea nouchali, Nymphaea lotus,* and *Eichhornia crassipes*) which were found in areas with deep and usually open standing water maintained for prolonged duration.

Cyperus articulatus-Typha angustifolia occurred at or just above the waterline where seasonal water level fluctuations and waves caused erosion and deposition. This repeated disturbance produced a zone dominated by annuals in the genera *Typha, Leersia, Cyperus, Echinochloa, Eichhornia* and *Nymphaea.* These were wetland dependent plant species that are tolerant to high water table.

Figure 4.4: The *Cyperus articulatus-Typha angustifolia* community type at western side.

Table 4.1: Synoptic table of Lake Chamo Wetland vegetation showing mean cover values of species within clusters.

SPECIES	COMMUNITY TYPES			
	1	2	3	4
Abutilon fruticosum	0.00	0.00	0.56	0.00
Acalypha racemosa	0.00	0.00	0.00	0.05
Achyranthes aspera	0.53	0.29	2.00	0.00
Acmella caulirhiza	0.11	0.00	0.00	0.00
Aeschynomene elaphroxylon	0.63	2.59	0.00	0.35
Amaranthus spinosus	0.00	0.29	0.00	0.00
Calpurnia aurea	0.00	0.29	0.00	0.00
Cayratia ibuensis	0.00	0.12	0.44	0.00
Cleome gynandra	0.00	0.29	0.00	0.00
Commelina diffusa	0.00	0.00	0.56	0.00
Cynodon aethiopicus	**6.68**	**6.29**	0.00	0.30
Cyperus articulatus	**4.42**	0.00	0.00	**7.00**
Cyperus conglomeratus	0.32	0.00	0.00	0.00
Cyperus latifolius	0.79	1.06	0.00	0.50
Echinochloa colona	0.00	0.29	0.00	0.00
Echinochloa pyramidalis	0.32	0.00	0.00	0.90
Eclipta prostrata	0.00	0.71	0.00	0.00
Eichhornia crassipes	0.00	0.00	0.00	0.30
Eleusine floccifolia	0.00	0.12	0.00	0.00
Enydra fluctuans	0.00	0.35	0.00	0.00
Ficus sycomorus	0.32	0.00	0.00	0.00

Geigeria alata	0.32	0.00	0.00	0.00
Gomphocarpus semilunatus	0.05	0.00	0.00	0.00
Hibiscus crassinervius	0.00	0.00	0.00	0.25
Hibiscus micranthus	0.00	0.29	0.00	0.00
Hibiscus vitifolius	0.00	0.71	0.00	0.00
Hydrocotyle ranunculoides	0.26	0.00	0.00	0.00
Indigofera atriceps	0.00	0.29	0.56	0.00
Ipomoea aquatica	1.05	0.29	0.00	0.40
Ipomoea eriocarpa	0.00	0.29	0.00	0.00
Hypoestes triflora	0.00	0.00	1.78	0.00
Kedrostis hirtellus	0.16	0.00	0.00	0.00
Lantana camara	0.32	0.65	0.00	0.00
Leersia hexandra	0.89	0.65	**6.22**	3.20
Leptadenia hastata	0.00	0.00	0.78	0.00
Leptochloa fusca	0.84	0.29	0.56	0.55
Mikania capensis	0.00	0.00	0.56	0.00
Nymphaea nouchali	0.00	0.00	0.00	0.60
Nymphaea lotus	0.26	0.00	0.00	0.25
Panicum maximum	0.37	0.00	0.00	0.00
Paspalidium geminatum	0.00	0.00	0.67	0.25
Pennisetum polystachion	0.00	0.41	0.00	0.00
Perotis patens	0.26	0.00	0.56	0.00
Phalaris arundinacea	0.00	0.82	0.00	0.00
Pluchea dioscoides	0.00	0.00	0.56	0.00
Pluchea ovalis	0.47	0.00	1.33	0.00
Potamogeton pucillus	0.00	0.00	0.00	0.25
Rubus steudneri	0.00	0.00	0.67	0.00
Sesbania sesban	3.89	0.47	0.56	2.15
Solanum incanum	0.00	**3.41**	0.00	0.30
Spilanthes costata	0.00	0.00	0.56	0.00
Thelypteris confluens	0.21	0.00	0.00	0.00
Typha angustifolia	0.00	0.35	0.00	**3.20**
Vernonia abyssinica	0.00	0.29	0.00	0.00
Vigna heterophylla	0.00	0.00	0.44	0.00
Xanthium strumarium	0.05	0.53	0.00	0.00

Table 4.2: Summary of wetland plant community types from Lake Chamo vegetation data

Agglomerative hierarchical relationships	Plant community types			
	1	2	3	4
Dominant species	*Cynodon aethiopicus* and *C. articulatus*	*C. aethiopicus* and *Solanum incanum*	*Leersia hexandra*	*C. articulatus* and *Typha angustifolia*
Mean cover values	6.68 and 4.42	6.29 and 3.41	6.22	7.00 and 3.20
Sub-dominant species	*Sesbania sesban* and *Ipomoea aquatica*	*Aeschynomene elaphroxylon* and *Lantana camara*	*Hypoestes triflora* and *Achyranthes aspera*	*Leersia hexandra* and *Sesbania sesban*
Shannon's diversity (H')	2.42	2.63	2.60	2.16
Shannon's evenness index (J)	0.75	0.80	0.87	0.75
Richness (S)	25	27	20	18
No of quadrats	19	17	9	20

4.1.3. Diversity of Plant Community Types

The Shannon-Wiener Diversity computed for four different plant communities (Table 4.2) showed that *Cynodon aethiopicus -Solanum incanum* community type had the highest species richness. Of the plant community types, *Cynodon aethiopicus -Solanum incanum* and *Leersia hexandra* were relatively most diverse. These community types occured in areas subject to floods of shorter duration and depth and have greater plant species diversity than those that occured in permanently innudated areas. *Leersia hexandra* (Community three) had the most eveness with very few dominat species. Community type four (*Cyperus articulatus-Typha angustifolia*) has the least diversity index, least richness and with least eveness index values.

4.1.4. Environmental Gradients Influencing Wetland Plant Communities

4.1.4.1. Multivariate Non-metric Multidimensional Scaling (NMDS)

The Plant community types were examined using non-metric multidimensional scaling (NMDS) ordination (Figure 4.5). NMDS was chosen because the tests can produce robust visualizations of data despite numerous zero-values and highly variable data with lack of normality (McCune and Grace 2002). Plant community types were clearly separated from one another in the ordination space (Figure 4.5). *Cyperus articulatus-Typha angustifolia* (community four) which mainly consisted of wetland dependent species was correlated with high water levels (Table 4.3, r^2=0.606, p=0.001) and less disturbed areas. On the other hand, *Cnodon aethiopicus-Solanum incanum* (community two) was highly correlated with disturbed areas (Table 4.3, r^2=0.463, p=0.001).

Table 4.3. Pearson (r^2) correlations of Nonmetric Multidimensional Scaling ordination axes with environmental variables of Lake Chamo vegetation. Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1, P values based on 999 permutations

Vectors	NMDS1	NMDS2	r^2	Pr(>r)
Depth	-0.986	-0.167	0.606	0.001***
Hydrogeo	0.935	-0.354	0.177	0.005*
Disturb	0.986	0.165	0.463	0.001***

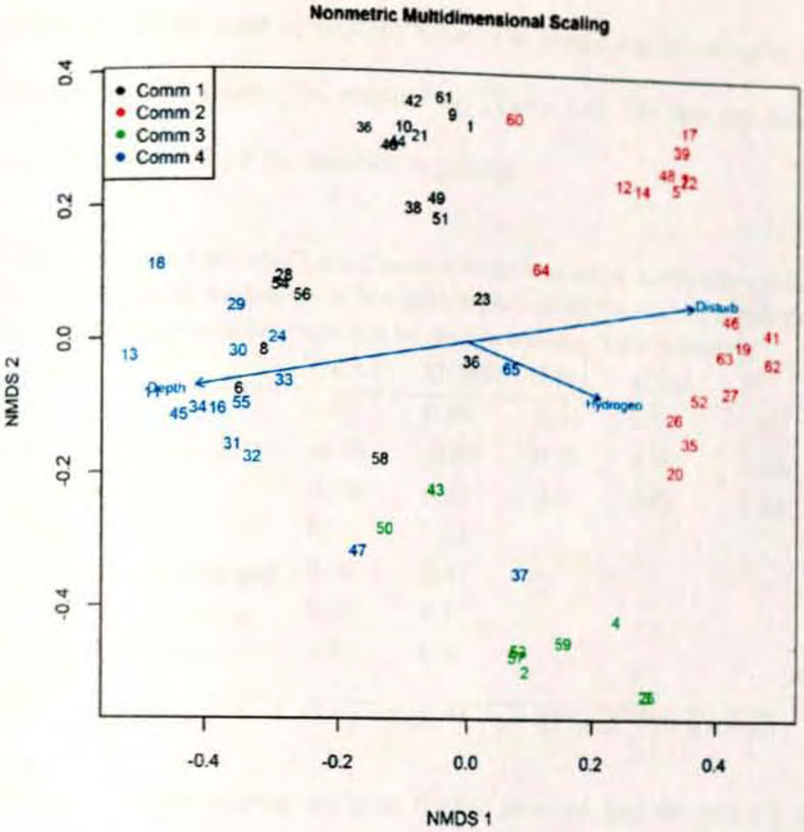


Figure 4.5. Nonmetric Multidimensional Scaling (NMDS) diagram of plots of Lake Chamo vegetation grouped by community types (communities 1 to 4). Vectors represent environmental variables: depth, hydrogeomorphology and disturbance.

4.1.4.2. Canonical Correspondence Analysis (CCA)

Although there is some overlap in floristic composition, plant community types had significantly different species assemblages that were identified using cluster analysis. The arrangement of plant communities on the CCA ordination for the study area (Figure 4.6a) reflected the influence of gradients representing disturbance, hydrogeomorphology and water depth on plant community composition patterns. The ANOVA test for all groups showed that water depth, disturbance and hydrogeomorphology were highly correlated to the floristic composition of the plant community types. The remaining environmental factors (Drainage, elevation and slope) had no significant relationships to the floristic composition and distribution of the plant community types. The proportion of variances explained by the first two axes was 40% and 37%, respectively (Table 4.4). The first two axes together accounted for 77% (Table 4.4) of the variation explained.

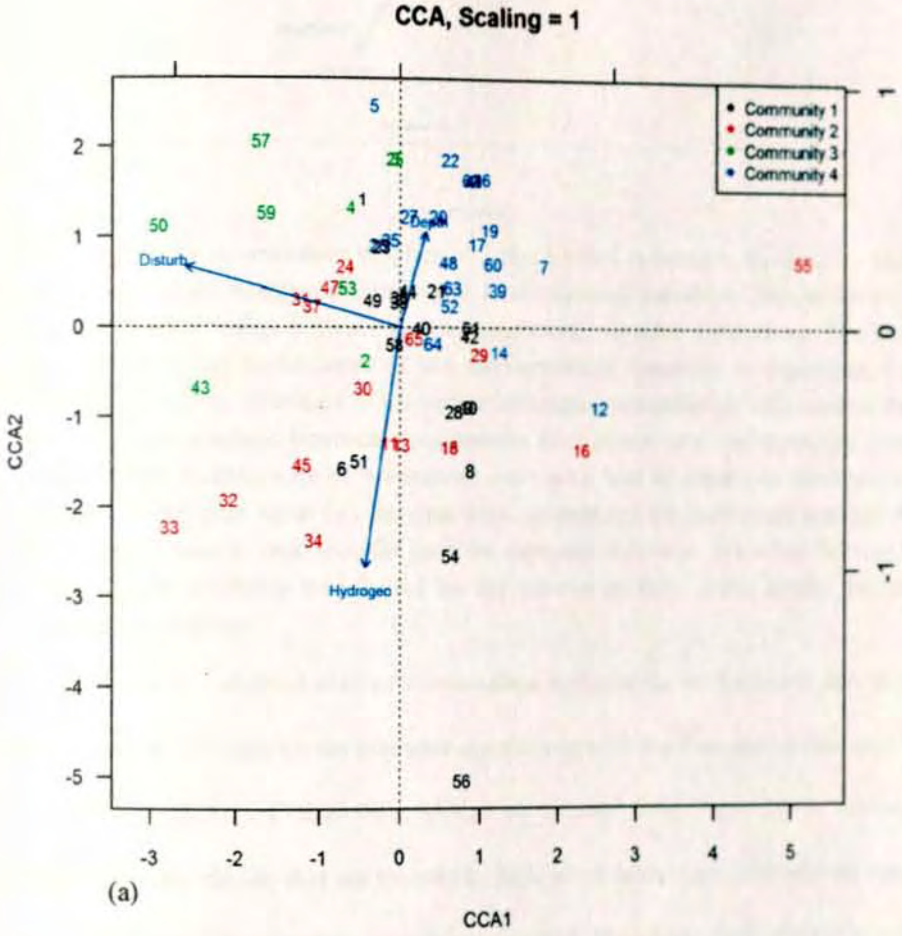
Table 4.4: CCA results of of Lake Chamo wetland vegetation. Canonical coefficients from the best-fit multiple regression models (ANOVA test), biplot scores for the constraining variables, eigenvalues and proportion of variances explained by the first two axes were indicated.

Variables	**CCA1**	**CCA2**	SSqs	MSqs	F	R^2	Pr(>f)
Depth	0.12	**0.39**	0.64	0.64	2.23	0.03	0.03*
Hydrogeomorphlogy	-0.16	**-0.99**	0.96	0.96	3.32	0.05	0.01**
Disturbance	**-0.96**	0.25	0.45	0.45	1.56	0.02	0.02*
Eigenvalues	0.26	0.23					
% of variance explained	0.40	0.37					
Cumulative proportion	0.40	0.77					
Species-environment correlations	0.83	0.81					

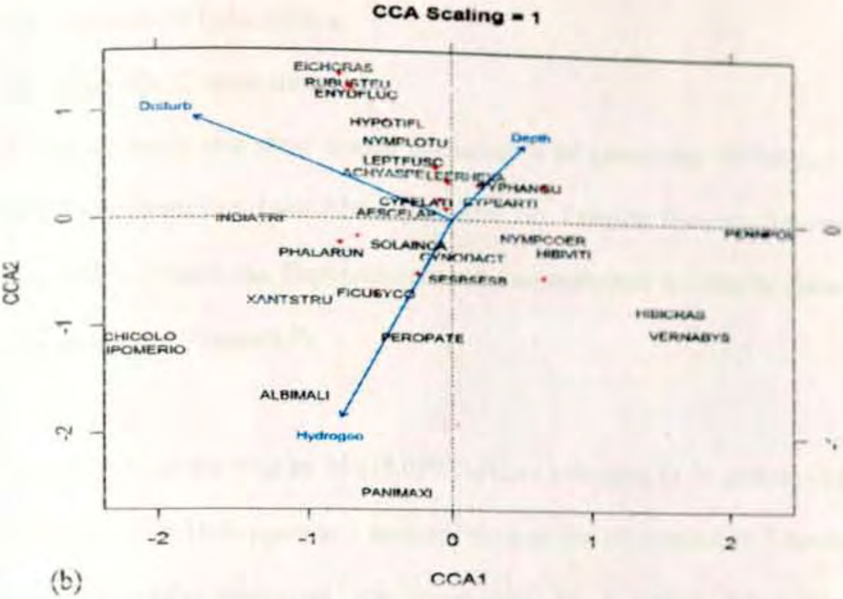
(* = 0.01 < p < 0.05, ** = p < 0.01 and *** = p < 0.001).

Canonical correspondence analyses further revealed that the primary gradient for species distribution was related to disturbance as indicated by a biplot score of -0.96, where as the second axis was mainly related to hydrogeomorphology (-0.99) and water depth (0.39) (Table 4.4). Disturbance was negatively related to the first axis.

Cyperus articulatus-Typha angustifolia (community four) on the upper right part of the CCA ordination (Figure 4.6a) was associated with high water levels and less drained areas. These groups most commonly occurred in areas characterized by the presence of standing or open water body with vegetation type occasionally used for grazing. In contrast, *Cynodon aethiopicus-Solanum incanum* (community two) was associated with low water levels, high disturbance and well or somewhat excessively drained areas that most commonly occurred in low lying dry terrestrial landscape. These groups most commonly occurred in areas characterized by relatively drier terrestrial landscape with well drained soils. *Cynodon aethiopicus-Cyperus articulatus* (community one) was characterized by low water levels and well drained areas; however, it was associated with decreasing disturbance. *Leersia hexandra* (community three), indicated mainly on the upper left side of the ordination space, was associated to high water levels and waterlogged areas but related to high disturbance. Disturbance rate was a strong factor differentiating community type one from three.



(a)



(b)

Figure 4.6(a). CCA ordination diagram of Lake Chamo vegetation showing the relationships between the plant community types and environmental variables. Angles between vectors indicate coorelationship between the environmental variables themselves. The length of the lines illustrates the significance of the environmental variables in explaining variation in species distribution. Direction of the vector indicates its coorelation with each of the axes. (b) Shows the relationships between plant species distribution and environmental factors. Only higher priority species with high variances are visible and all other less dominant species are indicated by red plus signs (+). Species were abbreviated by combining the first four letters from generic names and specific epithets (species data was provided in Appendix 1b). Environmental attributes represented by the vectors include: water depth, disturbance and hydrogeomorphology.

The ANOVA test showed marked relationships between the environment and the scores of many species. The species-environment correlations with the first and second axes were 0.83 and 0.81 respectively (Table 4.4). As can be inferred from Figure 4.6b, various wetland dependent plant species that are tolerant to high water table were indicated on upper side of CCA ordination. These include *Nymphaea nouchali*, *Nymphaea lotus*, *Potamogeton pucillus*, *Leersia hexandra*, *Cyperus articulatus* and *Typha angustifolia*. Their distribution was associated to high water table. The distribution of *Eichhornia crassipes* was related to highly disturbed areas.

4.2. Wetlands of Lake Abaya

4.2.1. Floristic Composition

A total of ninety two plant species belonging to 66 genera and 34 families were recorded from the wetlands of Lake Abaya (Appedix 1a). Families Poaceae, Asteraceae, Fabaceae, Cyperaceae, Solanaceae, Euphorbiaceae and Amaranthaceae account for about 56.99% of the total proportion (Figure 4.7).

Poaceae was represented by 14 (15.05%) species belonging to 11 genera; Cyperaceae by 13 species (13.98%) belonging to 2 genera; Fabaceae was represented by 7 species belonging to 4 genera while Asteraceae was represented by 6 species belonging to 6 genera. Euphorbiaceae was represented by 5 species belonging to 4 genera; Solanaceae was represented by 4 species belonging to 4 genera and Amaranthaceae was represented by 4 species belonging to 2 genera.

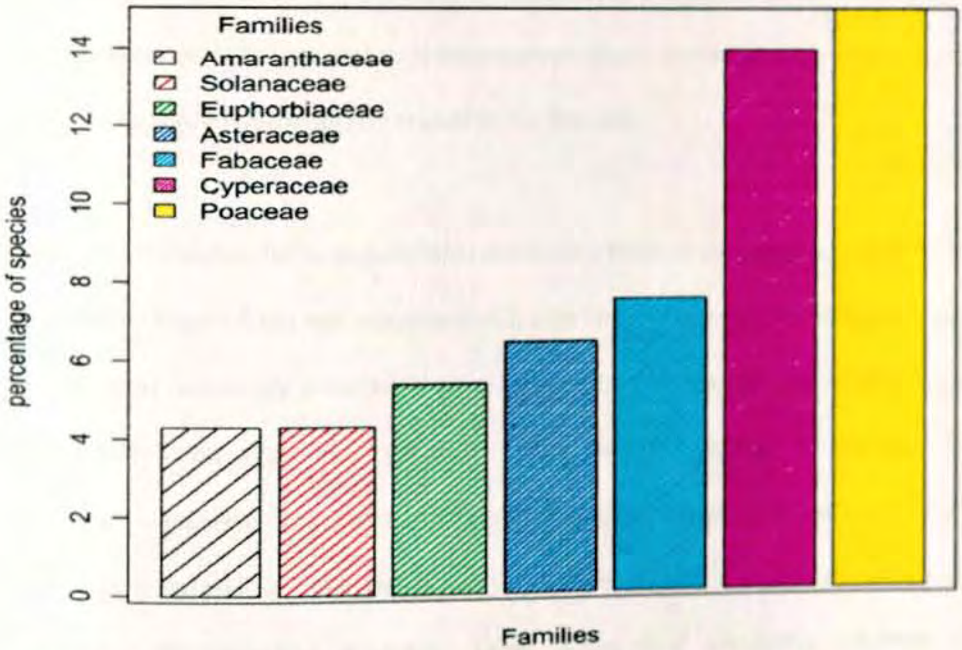


Figure 4.7: Families with the greatest representation in Lake Abaya wetland

distribution of the plant community types. The proportion of variances explained by the first two axes was 40% and 37%, respectively (Table 4.4). The first two axes together accounted for 77% (Table 4.4) of the variation explained.

Table 4.4: CCA results of of Lake Chamo wetland vegetation. Canonical coefficients from the best-fit multiple regression models (ANOVA test), biplot scores for the constraining variables, eigenvalues and proportion of variances explained by the first two axes were indicated.

Variables	**CCA1**	**CCA2**	SSqs	MSqs	F	R^2	Pr(>f)
Depth	0.12	**0.39**	0.64	0.64	2.23	0.03	0.03*
Hydrogeomorphlogy	-0.16	**-0.99**	0.96	0.96	3.32	0.05	0.01**
Disturbance	**-0.96**	0.25	0.45	0.45	1.56	0.02	0.02*
Eigenvalues	0.26	0.23					
% of variance explained	0.40	0.37					
Cumulative proportion	0.40	0.77					
Species-environment correlations	0.83	0.81					

(* = 0.01 < p < 0.05, ** = p < 0.01 and *** = p < 0.001).

Canonical correspondence analyses further revealed that the primary gradient for species distribution was related to disturbance as indicated by a biplot score of -0.96, where as the second axis was mainly related to hydrogeomorphology (-0.99) and water depth (0.39) (Table 4.4). Disturbance was negatively related to the first axis.

Cyperus articulatus-Typha angustifolia (community four) on the upper right part of the CCA ordination (Figure 4.6a) was associated with high water levels and less drained areas. These groups most commonly occurred in areas characterized by the presence of standing or open water body with vegetation type occasionally used for grazing. In contrast, *Cynodon aethiopicus-Solanum incanum* (community two) was associated with low water levels, high disturbance and well or somewhat excessively drained areas that most commonly occurred in low lying dry terrestrial landscape. These groups most commonly occurred in areas characterized by relatively drier terrestrial landscape with well drained soils. *Cynodon aethiopicus-Cyperus articulatus* (community one) was characterized by low water levels and

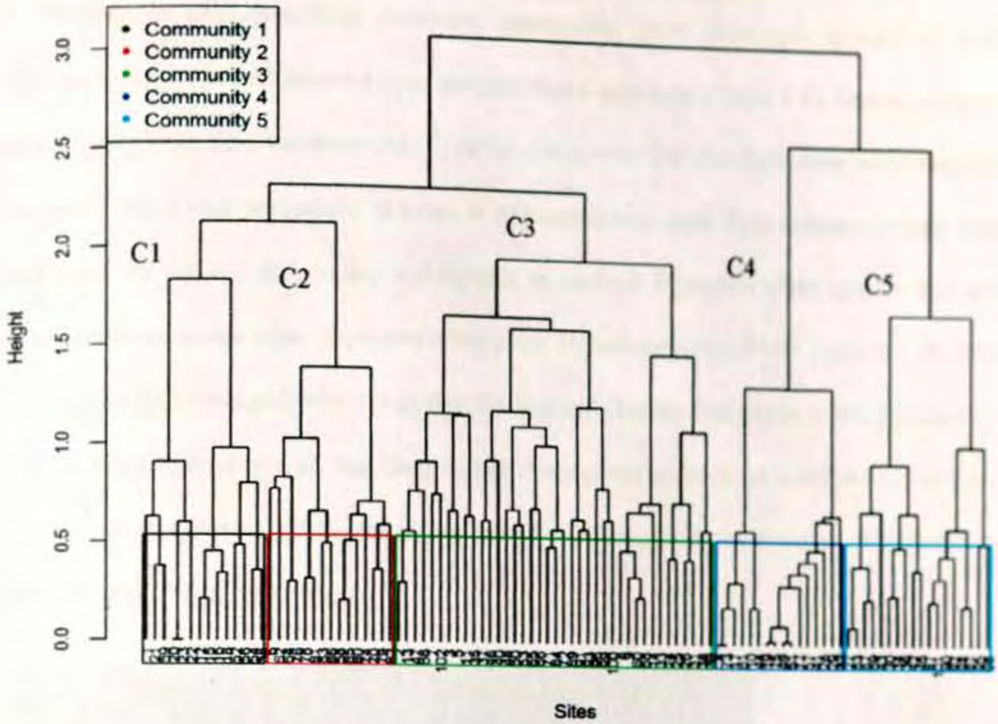


Figure 4.8: Dendrogram showing plant community types of Lake Abaya Wetland vegetation

Each plant community type is described below.

1. ***Cyperus articulatus* community type:** This community type was dominanted by *Cyperus articulatus. Cyperus laevigatus, Typha angustifolia, Cynodon aethiopicus, Aeschynomene elaphroxylon, Leersia hexandra* and *Eichhornia crassipes* were also important species with high mean cover values in the community type. This group included plant species that form wet meadow vegetation. Most of the plants in this community type were emergent macrophytes except few of them were floating plants such as *Nymphaea nouchali and Eichhornia crassipes*. Thus, in this community type, emergent plant species were more prominent than free floating, floating-leaf and submersed plants. This community type consists 13.7% of the stands most of which were from north and northwest of the lakeshore.

2. *Eichhornia crassipes-Pistia stratiotes* community type: Dominant species of this community type were *Eichhornia crassipes* and *Pistia stratiotes* (Figure 4.8). Species such as *Leptochloa fusca, Leersia hexandra, Cyperus articulatus* and *Aeschynomene elaphroxylon* also contributed high percentage of cover to this community type. This community type was dominated by aquatic and mainly hydrophytic or wetland dependent plant species that are tolerant to high water table. *Eichhornia crassipes, Nymphaea lotus, Pistia stratiotes, Wolffia arrhiza* and *Spirodela polyrrhiza* were free floating and floating-leaf plants in this community type. In this community type, free floating and floating-leaf plants were more prominent than emergent plants, but no submersed plants recorded. These stands were mainly distributed at the edge of the open water bodies.

Figure 4.8: Invasive species *Eichhornia crassipes* and *Pistia stratiotes* near Crocodile Ranch, Lake Abaya

3. *Cynodon aethiopicus* community type: This transitional vegetation type was rich in species and dominanted by *C. aethiopicus and Leersia hexandra*. Tree species recorded from this community type were *Ficus sycomorus, F. ovata, F. sur,* and *Kigelia africana*. Free floating and floating-leaf plants in this community type include *Eichhornia crassipes, Nymphaea nouchali, Wolffia arrhiza* and *Pistia stratiotes*. This community type was composed of both wetland and upland species and represented species rich community. It had a higher proportion of upland species than the other communities. Thus, free floating and floating-leaf plant species were less prominent than emergent species. All types of floristic composition (forbs, grasses, trees, shrubs and sedges) were observed. This type was distinct from the other wetland communities and showed species richness and composition approaching that of upland vegetation. This community type consisted of 32.5% of the stands which were sampled from south east, southwest and south end of the lake.

4. ***Typha angustifolia-Aeschynomene elaphroxylon* community type:** This community type (Figure 4.9) was dominanted by *Typha angustifolia* and *Aeschynomene elaphroxylon*. *Leersia hexandra* was another important species contributing most to the composition of this community type. *Ficus sycomorus* and *Aeschynomene elaphroxylon* were tree species in this community type. This community type consisted of 15.7% of the stands which were from north, northwest, and west of the lake. All of the plants in this community type were emergent macrophytes except *Potamogeton pucillus*, a submerged aquatic plant. In this community type, free floating and floating-leaf plants were not recorded. Emergent plants were more prominent than free floating, floating-leaf and submersed plants.

Figure 4.9: An extensive and dense stand of *Typha* in Lake Abaya Wetland near Bilate.

5. *Aeschynomene elaphroxylon* community type: This shruby marsh community type was dominanted by *Aeschynomene elaphroxylon* (Figure 4.10). *Nymphaea nouchali*, *Echinochloa pyramidalis*, *Leptochloa fusca*, *Eichhornia crassipes* and *Cyperus articulatus* were sub dominant species in this community type. This community type was represented by 17.6% of the stands sampled from north, northwest, west, and northeast of the lake. Free floating and floating-leaf plants recorded from this community type were (*Nymphaea nouchali*, *Pistia stratiotes*, *Spirodela polyrrhiza* and *Eichhornia crassipes*). Similar to community types two and four, this community type occurred on the edges of open and deeper standing water.

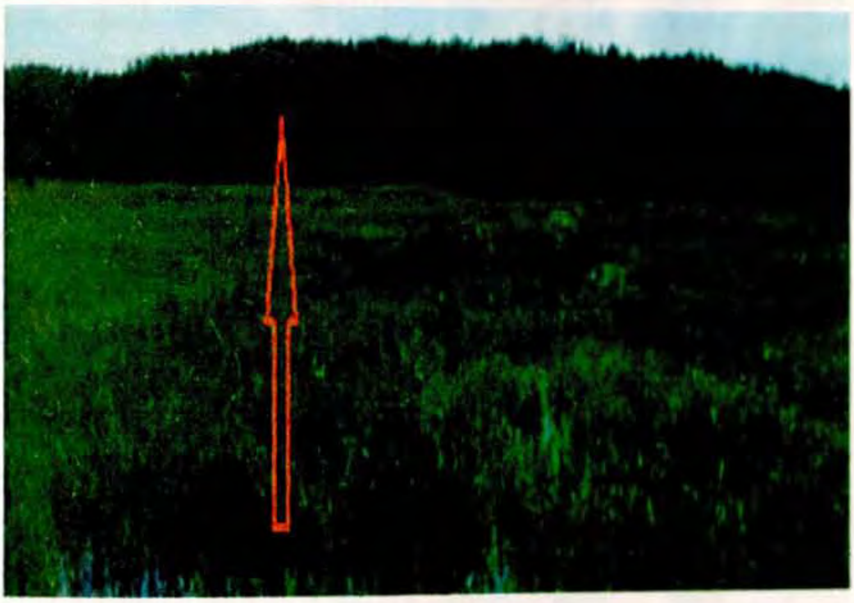


Figure 4.10: A dense stand of *Aeschynomene elaphroxylon* along the edge of open water

Table 4.5: Synoptic table of Lake Abaya Wetland vegetation showing mean cover values of species within clusters.

Species	Community types				
	C1	C2	C3	C4	C5
Acacia montigena	0.000	0.000	0.308	0.000	0.000
Acacia seyal	0.000	0.000	0.846	0.000	0.000
Acacia tortilis	0.000	0.000	0.128	0.000	0.000
Acalypha fruitcosa	0.000	0.000	0.436	0.000	0.000
Acalypha racemosa	0.000	0.000	1.359	0.000	0.000
Achyranthes aspera	0.000	0.000	0.795	0.000	0.000
Aeschynomene elaphroxylon	1.286	2.667	0.179	**4.750**	**7.111**
Ajuga leucantha	0.000	0.000	0.128	0.000	0.000
Aloe otallensis	0.000	0.000	0.308	0.000	0.000
Amaranthus dubius	0.000	0.000	0.282	0.000	0.000
Amaranthus spinosus	0.000	0.000	0.128	0.000	0.000
Phalaris arundinacea	0.000	0.467	0.000	0.000	0.000
Balanites aegyptiaca	0.000	0.467	0.589	0.000	0.000
Carissa spinarum	0.000	0.000	0.026	0.000	0.000
Cayratia ibuensis	0.000	0.000	0.069	0.000	0.000
Cissus quadrangularis	0.000	0.000	0.385	0.000	0.000
Clausena anisata	0.000	0.000	0.051	0.000	0.000
Commelina diffusa	0.000	0.000	0.103	0.000	0.000
Cordia africana	0.000	0.000	0.359	0.000	0.000
Croton macrostachyus	0.000	0.000	0.564	0.000	0.000
Cynodon aethiopicus	1.642	2.533	**3.564**	0.000	1.722
Cyperus alopecuroides	0.000	0.400	0.410	0.375	0.000
Cyperus articulatus	**4.714**	1.933	0.154	0.000	1.111
Cyperus digitatus	0.000	0.000	0.128	0.000	0.000
Cyperus distans	0.000	0.000	0.154	0.000	0.000
Cyperus grandibulbosus	0.429	0.000	0.000	0.000	0.000
Cyperus laevigatus	2.357	0.267	0.282	0.000	0.000
Cyperus latifolius	0.000	3.133	0.000	0.000	0.000
Cyperus papyrus	0.000	0.000	0.000	0.438	0.000
Cyperus rotundus	0.000	0.000	0.179	0.000	0.000
Cyperus subumbellatus	0.000	0.000	0.436	0.000	2.444
Echinochloa haploclada	0.500	0.000	0.000	0.000	0.000
Echinochloa pyramidalis	0.000	0.000	0.436	0.625	1.333
Eclipta prostrata	0.000	0.333	0.026	0.000	0.000
Eichhornia crassipes	0.923	**5.433**	0.154	0.000	1.222
Enneapogon desvauxii	0.357	0.000	0.385	0.000	0.000
Eragrostis japonica	0.000	0.000	0.154	0.375	0.000
Eriochloa fatmensis	0.000	0.000	0.000	0.250	0.000
Euphorbia tirucalli	0.000	0.000	0.154	0.000	0.000
Ficus ovata	0.000	0.000	0.538	0.000	0.000
Ficus sur	0.000	0.000	0.308	0.000	0.000
Ficus sycomorus	0.000	0.000	1.000	0.438	0.000

Geigeria alata	0.000	0.000	0.231	0.000	0.000
Gossypium barbadense	0.000	0.000	0.179	0.000	0.000
Grewia ferruginea	0.000	0.000	0.128	0.000	0.000
Grewia villosa	0.000	0.000	0.000	0.000	0.278
Hippocratea africana	0.000	0.000	0.154	0.000	0.000
Hypoestes forskaolii	0.000	0.000	0.231	0.000	0.000
Ipomoea aquatica	0.000	0.133	0.000	0.500	0.556
Ipomoea eriocarpa	0.000	0.000	0.077	0.563	0.167
Kigelia africana	0.000	0.000	0.179	0.000	0.000
Leersia hexandra	2.643	2.667	2.154	0.688	0.556
Leptadenia arborea	0.000	0.000	0.051	0.000	0.000
Leptochloa fusca	0.357	2.067	0.026	0.563	1.556
Leucas deflexa	0.000	0.000	0.179	0.000	0.000
Ludwigia stolonifera	0.000	0.000	0.103	0.000	0.000
Mangifera indica	0.000	0.000	0.051	0.000	0.000
Maytenus arbutifolia	0.000	0.333	0.154	0.000	0.000
Maytenus senegalensis	0.000	0.000	0.538	0.000	0.111
Melhania ovata	0.000	0.200	0.000	0.000	0.000
Nymphaea lotus	0.000	0.600	0.000	0.000	0.000
Nymphaea nouchali	0.429	0.000	0.128	0.000	1.556
Phragmates karka	0.000	0.000	0.000	0.313	0.000
Pistia stratiotes	0.000	**4.533**	0.128	0.000	0.389
Plecthrantus barbatus	0.000	0.000	0.128	0.000	0.000
Pluchea ovalis	0.000	0.000	0.872	0.000	0.000
Potamogeton pucillus	0.000	0.200	0.000	0.125	0.000
Pulcaria schimperi	0.000	0.000	0.077	0.000	0.000
Senna didymobotrya	0.000	0.000	0.359	0.000	0.333
Senna septemtrionalis	0.000	0.000	0.000	0.000	0.278
Sesbania sesban	0.000	0.067	0.179	0.000	0.000
Solanum incanum	0.000	0.000	0.949	0.000	0.000
Sorghum verticilliflorum	0.357	0.333	0.205	0.813	0.000
Spirodela polyrrhiza	0.000	0.000	0.026	0.000	0.222
Trichilia emetica	0.000	0.000	0.231	0.000	0.000
Typha angustifolia	2.471	0.400	0.308	**7.875**	0.000
Withania somnifera	0.000	0.000	0.077	0.000	0.000
Wolffia arrhiza	0.000	0.533	0.179	0.000	0.000
Xanthium strumarium	0.000	0.000	0.615	0.063	0.333

Table 4.6: Summary of wetland plant community types from Lake Abaya vegetation data.

Agglomerative hierarchical relationships	Plant community types				
	1	2	3	4	5
Dominant species	*Cyperus articulatus*	*E. crassipes* *P. stratiotes*	*Cynodon aethiopicus*	*T. angustifolia* *A.elaphroxylon*	*Aeschynomene elaphroxylon*
Mean cover values	4.71 and 3.36	5.43 and 4.53	3.56	7.88 and 4.75	7.11
Sub-dominant species	*T. angustifolia, C. aethiopicus, A.elaphroxylon* and *L. hexandra*	*L. fusca, L. hexandra, C. articulatus, C. aethiopicus,* and *A.elaphroxylon*	*Leersia hexandra, F. sycomorus* and *A. fruitcosa*	*Leersia hexandra*	*C. aethiopicus, N. nouchalii, E. pyramidalis, L. fusca, E. crassipes, C. articulatus*
Shannon's diversity x(H)	2.10	2.56	**3.64**	1.87	2.31
Shannon's eveness (J)	0.84	0.82	**0.87**	0.67	0.80
Richness (S)	12	23	**67**	16	18
No. quadrats	14	15	**39**	16	18

4.2.3. Diversity of Plant Community Types

The Shannon-Wiener Diversity computed for five different plant communities (Table 4.6) showed that community type three (*Cynodon aethiopicus*) which was found in relatively dry terrestrial landscape and exposed for disturbance was the most diverse and has the highest species richness and eveness. Community type four (*Typha angustifolia-Aeschynomene elaphroxylon*) which occurred in deeper standing water around the open water zones and experiencing prolonged inundation had the least diversity index and had the least even distribution of species. Community type one (*Cyperus articulatus*) was the least in species richness and occurred in deeper water next to community four.

4.2.4. Environmental Gradients Influencing Wetland Plant Communities

4.2.4.1. Multivariate Non-metric Multidimensional Scaling (NMDS)

Multivariate Non-metric Multidimensional Scaling (NMS) resulted in a 2-dimensional solution with a final stress of 0.255 (Figure 4.11). The first axis was most correlated with water depth (Table 4.7, r^2 =0.248, p=0.001), Hydrogeomorphology (Table 4.7, r^2 =0.167, p=0.003) and slope (Table 4.7, r^2 =0.334, p=0.001) (Table 4.7). Community type five (*Aeschynomene elaphroxylon*) was mostly correlated with drainage (Table 4.7, r^2 =0.067, p=0.039) where as community type three was highly correlated with slope (Table 4.7, r^2 =0.334, p=0.001). *Typha angustifolia-Aeschynomene elaphroxylon* (community four) which mainly consisted of wetland dependent species was correlated with higher water depth ((Table 4.7, r^2=0.248, p=0.001).

Table 4.7. Pearson (r^2) correlations of Nonmetric Multidimensional Scaling ordination axes with environmental variables of Lake Abaya vegetation. Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1, P values based on 999 permutations

Vectors	NMDS1	NMDS2	r^2	Pr(>r)
Depth	-0.793	-0.609	0.248	0.001***
Drainage	-0.942	0.335	0.067	0.039
Hydrogeo	0.906	0.423	0.167	0.001***
Slope	0.968	0.250	0.334	0.001***

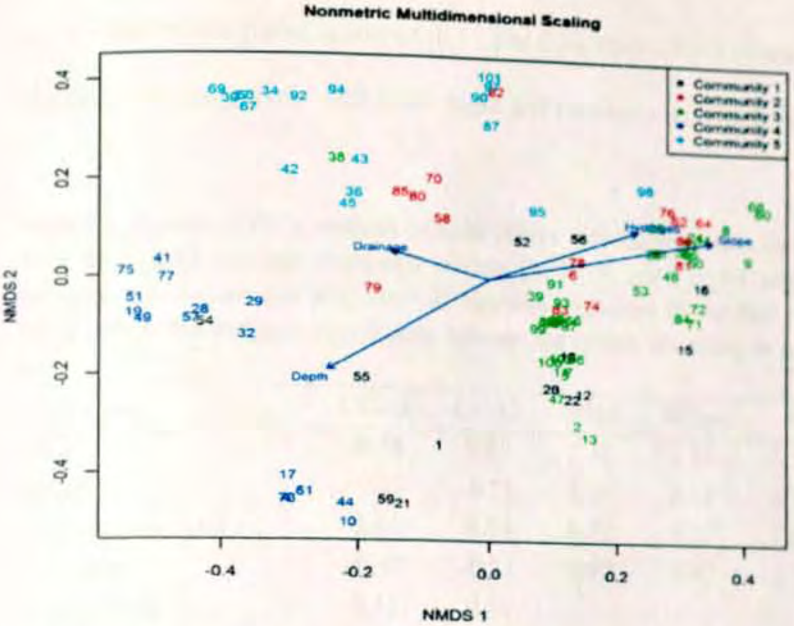


Figure 4.11. Non-metric Multidimensional Scaling (NMDS) diagram of plots of Lake Abaya vegetation grouped by community type (communities 1 to 5). Vectors represent environmental variables: depth, hydrogeomorphology, drainage and slope.

4.2.4.2. Canonical Correspondence Analysis (CCA)

Species and plots ordination in the space defined by the first two CCA axes are shown in Figures 4.12 (a) and (b). CCA ordination illustrates the relationship of the four environmental variables (water depth, drainage, slope and hydrogeomorphology) to five community types and to species distribution pattern. The first two axes together accounted for 63% (Table 4.8) of the variation explained. The proportion of variances explained by these axes was 36% and 27%, respectively (Table 4.8).

Results from ANOVA test showed that water depth, slope, drainage and hydrogeomorphology were significantly related to the floristic composition of the plant community types. The first axis extracted by the analysis was closely related to the drainage and slope, as indicated by the biplot scores of -0.43 and -0.78 (Table 4.8). The second axis extracted by the analysis was more closely related to water depth and hydrogeomorphology, as indicated by the biplot scores of -0.71 and 0.54, respectively (Table 4.8). The second axis was associated negatively with water depth and positively with hydrogeomorphology.

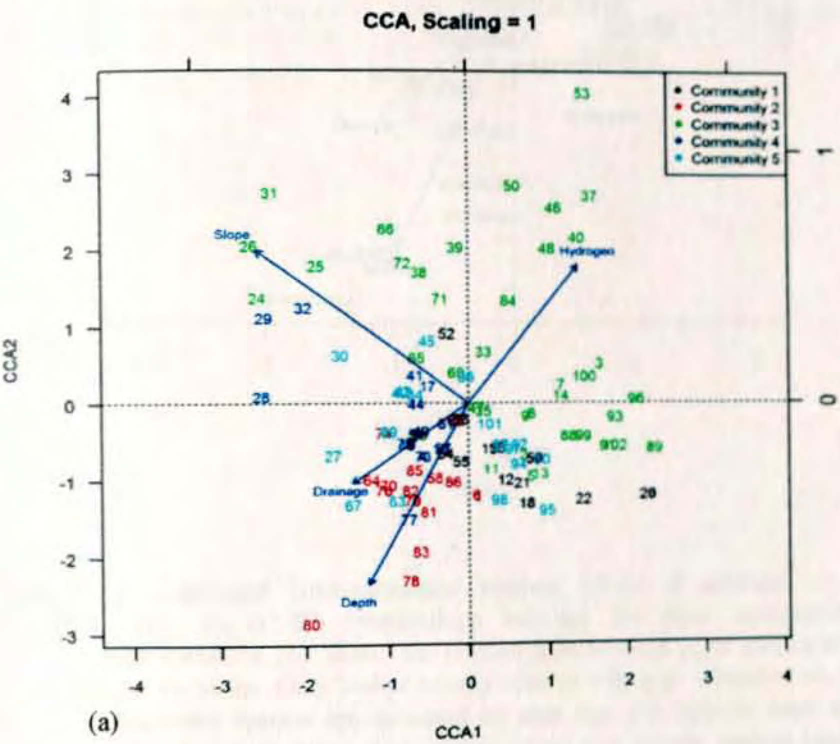
Table 4.8. Results of CCA analysis of Lake Abaya wetland vegetation data. Canonical coefficients from the best-fit multiple regression models (ANOVA test), biplot scores for the constraining variables, eigenvalues and proportion of variances explained by the first two axes were indicated. Factor values that differed significantly between the groups according to an ANOVA are shown in bold.

Variables	**CCA1**	**CCA2**	**SSqs**	**MSqs**	**F**	**R2**	**Pr(>F)**
Slope	**-0.78**	0.60	1.32	1.32	3.78	0.03	0.01**
Depth	-0.38	**-0.71**	2.13	2.13	6.10	0.05	0.01**
Hydrogeomorphlogy	0.41	**0.54**	0.71	0.71	2.02	0.02	0.05*
Drainage	**-0.43**	-0.31	0.97	0.97	2.78	0.02	0.01**
Eigenvalues	0.41	0.31					
% variance explained	0.36	0.27					
Cumulative % variance	0.36	0.63					
Species enviroment correlations	0.85	0.74					

(* = $0.01 < p < 0.05$, ** = $p < 0.01$ and *** = $p < 0.001$).

Ordination diagram of CCA (Figure 4.12a) for plots and environmental factors showed that *Eichhornia crassipes-Pistia stratiotes* (community two) and *Typha angustifolia-Aeschynomene elaphroxylon* (community four) were found in areas with high water level and poor drainage. Therefore, distribution of these community types was significantly affected by hydrologic factors such as water depth, drainage and hydrogeomorphology. These community types were consisted of wetland dependent plant species that are tolerant to high water table which most commonly occur in waterlogged areas characterized by presence of standing or permanently flowing water for most of the year. This wetland dependent community type also occurred in permanently flooded areas as well as in and around the edge of open water bodies.

Alternatively, *Cynodon aethiopicus* (community type 3) with large number of plots (in the upper part of the ordination space (Figure 4.12b) was found in excessively drained areas with high disturbance and low water level. These groups also commonly occurred in areas characterized by low lying dry terrestrial landscape with well drained soils. Water depth and hydrogeomorphology were strong factors differentiating these groups from other community types. Slope was a strong factor differentiating community type five (*Aeschynomene elaphroxylon*) from others. It was relatively intact and pristine or semi-natural vegetation found in areas occasionally used for grazing activities.



(a)

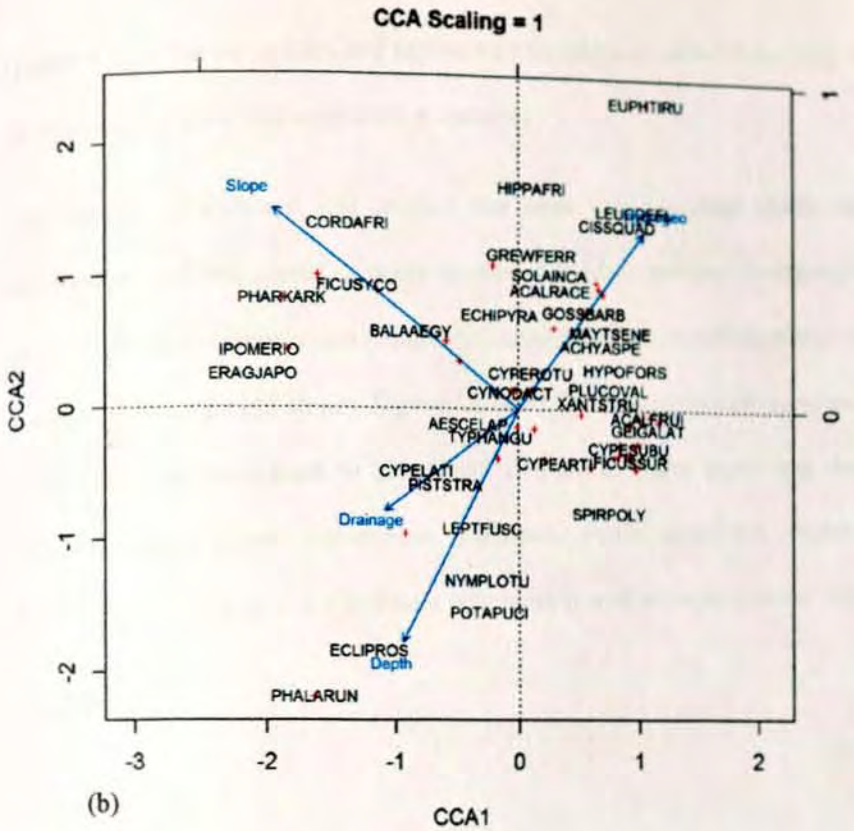


Figure 4.12: Canonical correspondence analysis (CCA) of wetlands of Lake Abaya vegetation. (a): shows the relationships between the plant community types and environmental variables, (b): shows the relationships between plant species distribution and environmental variables. Only higher priority species with high variances are visible and all other less dominant species are indicated by plus sign (+). Species were abbreviated by combining the first four letters from generic names and specific epithets (species data are provided in Appendix 1a). Environmental attributes represented by the vectors included water depth, slope, drainage and hydrogeomorphology. The vectors representing environmental gradients point in the direction of the most rapid change in each variable.

Analysis of variance showed that there was a strong relationship between species and environmental factors such as water depth ($p<0.01$), drainage ($p<0.01$), hydrogeomorphology ($p<0.05$) and slope ($p<0.01$). The species and environment correlations with the first axis was 0.85 and the second axis was 0.74 (Table 4.8). Canonical correspondence analysis (CCA)

(Figure 4.12b) for the species and explanatory variables revealed essentially the same pattern as ordination of plots and explanatory variables.

The analysis of variance also showed that there was a marked relationship between the environment and the scores of many species. The plant species *Pharagmatis karka, Cordia africana, Ficus sycomorus* and *Eragrostis japonica* had strong relationships with the first axis (more closely related to slope). *Euphorbia tirucalli, Hippocratea africana* and *Leucas deflexa* were more closely related to areas with decreasing water depth and drainage), whereas *Phalaris arundinacea, Eichhornia crassipes, Pistia stratiotes, Nymphaea lotus* and *Potamogeton pucillus* had significant relashinship with increasing water depth and drainage.

4.3. Fincha'a-Chomen Marsh

4.3.1. Floristic Composition

Ninety two plant species were recorded from Fincha'a-Chomen marshes (Appendix 1c). The specimens identified belong to 67 genera and 35 families. Only six families (Cyperaceae, Poaceae, Asteraceae, Fabaceae, Lamiaceae and Polygonaceae) account about 62% of the total proportion (Figure 4.13). Cyperaceae was represented by the highest number of species. It was represented by 26 species belonging to 7 genera. Poaceae was represented by 11 species belonging to 9 genera; Asteraceae by 7 species belonging to 6 genera; Fabaceae was represented by 5 species belonging to 5 genera while Lamiaceae was represented by 4 species belonging to 4 genera. The family Polygonaceae was represented by 3 species belonging to 2 genera. Families Solanaceae, Myrtaceae, Commelinaceae and Amaranthaceae were represented by 2 species each belonging to 2 genera. Families Chenopodiaceae, Apiaceae and Onagraceae were represented by 2 species each belonging to one genus. The remaining families were represented by one species each. Forbs occupied the highest floristic composition followed by sedges, grasses and shrubs. Forbs and sedges together contributed to 69% of the floristic composition.

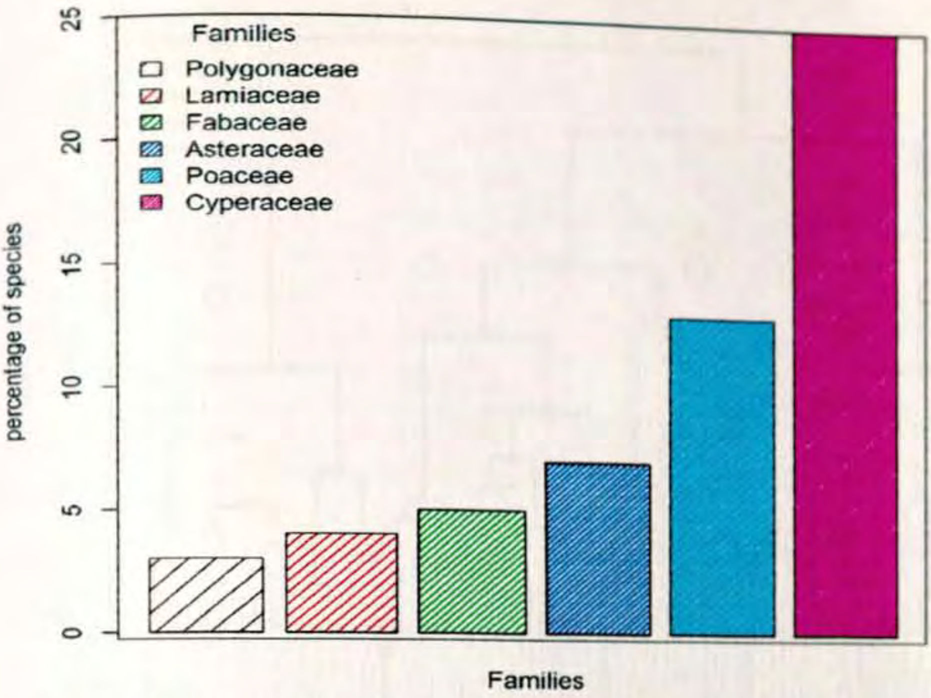


Figure 4.13: Families with the greatest representation in Fincha'a-Chomen vegetation.

4.3.2. Description of Plant Community Types

Based on the cluster analysis output and the resulting synoptic table and ecological evaluation in the field, four plant community types (clusters) were identified between 1.0 to 2.0 heights (0.30 - 0.60 dissimilarity levels) of the dendrogram (Figure 4.14). The plant community types were named by the dominant species, which occur in each group, using the highest synoptic values of plant species (Table 4.9). Communities with their dominant and sub-dominant species, the number of relevés they contained and diversity index are given in Table 4.10. Species such as *Commelina diffusa, Cyperus dichroostachyus, Eragrostis tenuifolia, Lindernia rotundata, Ranunculus multifidus, Schoenoplectus confusus, Persicaria decipiens, Cynodon aethiopicus, Cyperus latifolius, Leersia hexandra* and *Trifolium rueppellianum* were widely and frequently distributed. Each of these species occurred in more than 11.6% of the quadrats.

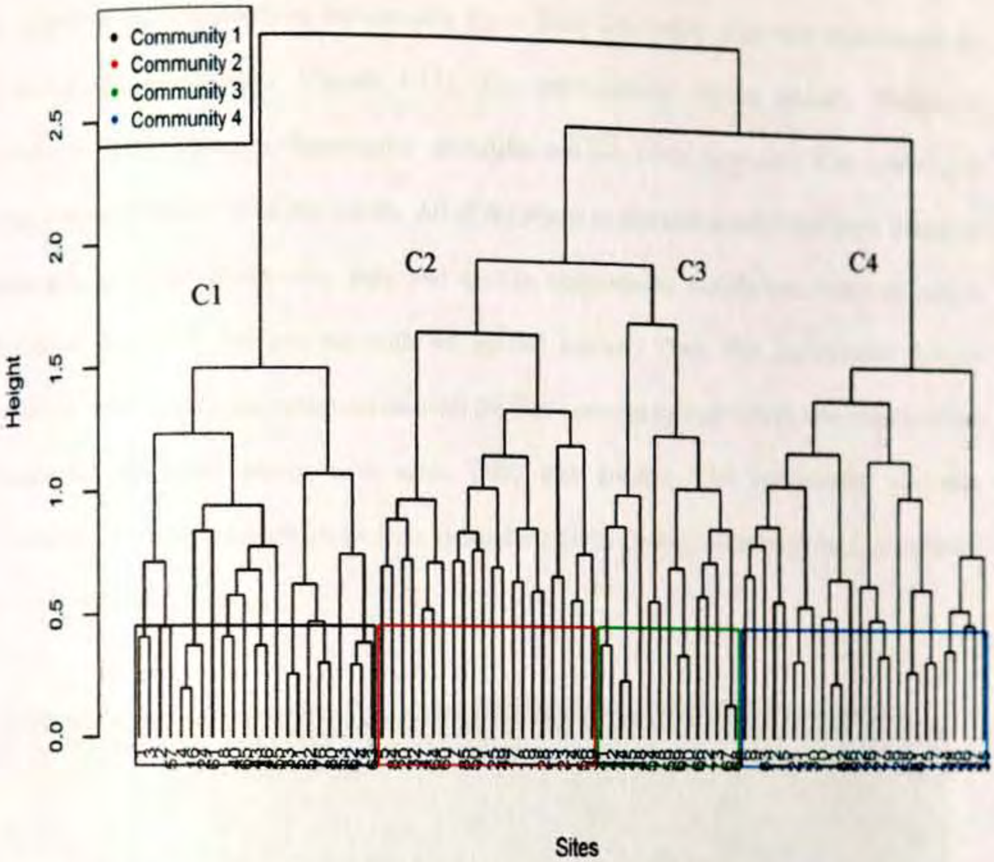


Figure 4.14: Dendrogram showing plant community types of Fincha'a-Chomen vegetation.

Each plant community type is described below.

1. ***Lindernia rotundata-Trifolium rueppellianum-Cynodon aethiopicus* community:** This community type was dominanted by *Lindernia rotundata, Trifolium rueppellianum* and *Cynodon aethiopicus* (Appendix 5). *Satureja paradoxa. Leersia hexandra. Cyperus esculentus. Eragrostis tenuifolia* and *Brachiaria brizantha* were subdominant species in terms of mean cover values. This community type consisted of 26.7% of the stands. All of the plants in this community type were emergent macrophytes without submersed, free floating and floating-leaf plants. This community type had floristic composition consisting mainly of sedges and grasses followed by forbs and some upland species.

2. *Cyperus dichroostachyus* community type: This community type was dominanted by *Cyperus dichroostachyus* (Figure 4.15). The subdominant species include *Thelypteris confluens*, *Xyris capensis*, *Ranunculus multifidus* and *Lindernia rotundata*. This community type consisted of 25.6% of the stands. All of the plants in this community type were emergent macrophytes. This community type had species composition mainly consisting of sedges followed by forbs and grasses with no upland species. Thus, this community showed relatively similar floristic composition with the first community type which was largely sedge dominated emergent plants with some forbs and grasses. This community was also characterized by species which include hydrophilic forbs *Ludwigia stolonifera*, *L. abyssinica* and *Chenopodiuim album*.

Figure 4.15: *Cyperus dichroostachyus* community type

3. *Schoenoplectus corymbosus-Cyperus latifolius* community type: *Schoenoplectus corymbosus* and *Cyperus latifolius* were the dominant species in this community type (Appendix 5). The subdominant species include *Schoenoplectus confusus*. *Polygonum amphibium*, *Persicaria decipiens*, *Eragrostis tenuifolia*, *Eriochloa fatmensis* and *Typha latifolia*. *Nymphaea nouchali* was a floating-leaf plant in this community type. This community type consisted of only 17.4% of the stands. It had similar floristic composition to the first and the second community types which were largely sedge dominated emergent vegetation with some forbs and grasses.

4. ***Panicum hygrocharis*** **community type:** This community type was dominated by *Panicum hygrocharis* which is the most important perennial stoloniferous grass species forming floating islands. *Persicaria decipiens, Schoenoplectus confusus, Persicaria senegalensis, Lindernia rotundata, Commelina diffusa* and *Cyperus latifolius* were subdominant species of this community type. This community type consisted of 30% of the stands. All of the plants in this community type were emergent macrophytes. The floristic composition of this community type consisted mainly of forbs followed by sedges and grasses with no upland species.

Table 4.9: Synoptic Table of Fincha'a-Chomen vegetation showing mean cover values of species within clusters.

Species	Community types			
	C1	C2	C3	C4
Aeschynomene schimperi	0.000	0.273	0.800	0.000
Ajuga leucantha	0.000	0.227	0.000	0.000
Amaranthus spinosus	0.261	0.000	0.000	0.000
Ascolepis capensis	0.217	0.273	0.000	0.346
Brachiaria brizantha	1.217	0.318	0.000	0.000
Brachiaria pubescence	0.000	0.000	0.333	0.000
Chenopodiuim album	0.000	0.136	0.000	0.000
Chenopodiuim schroderianum	0.000	0.000	0.000	0.423
Commelina diffusa	0.565	0.500	0.400	1.231
Croton macrostachyus	0.261	0.000	0.000	0.000
Cynodon aethiopicus	**4.913**	0.000	0.000	0.000
Cyperus assimilis	0.261	0.000	0.000	0.000
Cyperus atroviridis	0.000	0.500	0.000	0.731
Cyperus dichroostachyus	0.000	**3.455**	0.000	0.731
Cyperus digitatus	0.217	0.864	0.000	0.692
Cyperus elegantulus	0.000	0.682	0.467	0.000
Cyperus esculentus	1.391	0.000	0.000	0.192
Cyperus grandibulbosus	0.217	0.000	0.000	0.000
Cyperus latifolius	0.261	0.000	**2.867**	1.000
Cyperus longibracteatus	0.000	0.227	0.000	0.000

Cyperus munditti	0.000	0.318	0.000	0.000
Cyperus nitidus	0.739	0.545	0.667	0.192
Cyperus pectinatus	0.000	0.046	0.000	0.000
Cyperus rotundus	0.000	0.000	0.733	0.000
Cyperus rubicundus	0.000	0.000	0.733	0.000
Cyperus welwitschii	0.000	0.273	0.000	0.000
Echinochloa stagnina	0.000	0.000	0.800	0.000
Echinops hispidus	0.217	0.000	0.000	0.000
Eleusine floccifolia	0.000	0.227	0.600	0.000
Eragrostis tenuifolia	1.130	0.636	1.533	0.269
Eriocaulon schimperi	0.217	0.273	0.000	0.000
Eriochloa fatmensis	0.000	0.000	1.867	0.000
Eriochrysis pallida	0.000	0.227	0.000	0.000
Fimbristylis complanata	0.000	0.362	0.000	0.269
Fimbristylis Ferruginea	0.000	0.273	0.000	0.000
Floscopa glomerata	0.261	0.955	0.733	0.000
Gomphocarpus semilunatus	0.000	0.636	0.133	0.000
Hydrocotyle mannii	0.000	0.500	0.333	0.038
Hydrocotyle ranunculoides	0.000	0.227	0.000	0.000
Hypericum pepidifolium	0.000	0.000	0.000	0.231
Hypoxis vilosa	0.304	0.000	0.000	0.000
Juncus oxycarpus	0.000	0.318	0.000	0.462
Kyllinga odorata	0.217	0.682	0.000	0.000
Kyllinga polyphylla	0.261	0.227	0.000	0.000
Panicum hygrocharis	1.478	0.545	0.000	**6.346**
Lindernia rotundata	**5.261**	2.955	0.733	1.115
Liphocarpha constricta	0.217	0.000	0.000	0.000
Ludwigia abyssinica	0.000	0.046	0.000	0.000
Ludwigia stolonifera	0.000	0.955	0.000	0.000
Mentha aquatica	0.217	0.000	0.000	0.000
Nymphaea nouchali	0.000	0.000	0.333	0.000
Pennisetum thunbergii	0.783	0.273	0.000	0.000
Persicaria decipiens	0.435	0.955	1.933	1.615
Phagnalon phagnaloides	0.087	0.227	0.000	0.000
Plantago lanceolata	0.000	0.136	0.000	0.000
Plectranthus punctatus	0.609	0.000	0.000	0.192
Polygonum amphibium	0.304	0.273	2.267	0.423
Persicaria senegalensis	0.000	0.000	0.000	1.269
Ranunculus multifidus	0.000	1.227	0.333	0.885
Rubus stuedneri	0.000	0.227	0.000	0.000
Satureja paradoxa	1.087	0.227	0.333	0.192
Satyrium brachypetalum	0.000	0.136	0.000	0.000
Sesbania sesban	0.000	0.000	0.000	0.269
Schoenoplectus confusus	0.000	0.818	2.467	1.385
Schoenoplectus corymbosus	0.000	0.000	**2.933**	0.308
Sphaeranthus suaveolens	0.000	0.227	0.333	0.000

Spilanthes costata	0.000	0.227	0.000	0.654
Thelypteris confluens	0.000	1.591	0.000	0.462
Trifolium rueppellianum	**4.522**	0.864	0.000	0.000
Typha latifolia	0.000	0.545	1.000	0.000
Vernonia abyssinica	0.000	0.500	0.000	0.000
Xyris capensis	0.000	1.909	0.000	0.769

Table 4.10: Summary of wetland plant community types from Fincha-Chomen vegetation data

Agglomerative hierarchical relationships	**plant community types**			
	1	**2**	**3**	**4**
Dominant species	*L. rotundata, T. rueppellianum* and *C. aethiopicus*	*C. dichroostachyus*	*S. corymbosus* and *C. latifolius*	*P. hygrocharis*
Mean cover values	5.26, 4.52 and 4.91	3.455	2.93 and 2.87	6.35
Sub-dominant species	*S. paradoxa, P. hygrocharis, C. esculentus, E. tenuifolia, B. brizantha*	*T. confluens, X. capensis, R. multifidus* and *L. rotundiata*	*S. confusus, P. amphibium, P. decipiens, E. tenuifolia, E. fatmensis* and *T. latifolia*	*P. decipiens, S. confusus, P. senegalensis, L. rotundata, C. diffusa* and *C. latifolius*
Shannon's diversity index	2.70	**3.47**	2.88	2.73
Shannon's eveness index	0.80	0.89	0.90	0.83
Richness	30	49	25	28
No. of quadrats	23	22	15	26

4.3.3. Diversity of Plant Community Types

The diversity indexes for the four communities (Table 4.10) show that community two (*Cyperus dichroostachyus*) had the highest score. Community type one (*Lindernia rotundata-Trifolium rueppellianum-Cynodon aethiopicus*) and four (*Panicum hygrocharis*) had relatively low diversity index values. Community type two was the highest in species richness whereas community type three (*Schoenoplectus corymbosus-Cyperus latifolius*) was the least. Community type one had the least even distribution.

4.3.4. Environmental Gradients Influencing Wetland Plant Communities

4.3.4.1. Multivariate Non-metric Multidimensional Scaling (NMDS)

Although there is some overlap, community types were separated from one another in the ordination space (Figure 4.16). Community type one (*Lindernia rotundata-Trifolium rueppellianum-Cynodon aethiopicus*) which mainly consisted of terrestrial species was positively correlated with disturbance (Table 4.11, r^2 =0.350, p=0.001) with well drained soils (Table 4.11, r^2 =0.443, p=0.001) in an elevated areas (Table 4.11, r^2 =0.315, p=0.001). Plant community type three (*Schoenoplectus corymbosus-Cyperus latifolius*) which mainly consisted of wetland dependent species was positively correlated with water depth (Table 4.11, r^2 =0.101, p=0.01). This plant community type mainly occurred in areas with higher water level, poor drainage and least disturbance. Community type four (*Panicum hygrocharis*) was negatively correlated with elevation (Table 4.11, r^2 =0.32, p=0.001) as it occurred in nearly flat areas with no slope.

Table 4.11. Pearson (r^2) correlations of Nonmetric Multidimensional Scaling ordination axes with environmental variables of Fincha'a-Chomen Marsh vegetation. Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1, P values based on 999 permutations

Vectors	NMDS1	NMDS2	r^2	Pr(>r)
Depth	0.762	-0.648	0.101	0.008**
Hydrogeo	-0.895	0.446	0.228	0.001***
Drainage	0.867	-0.498	0.443	0.001***
Disturb	-0.601	0.799	0.350	0.001***
Slope	-0.625	0.781	0.094	0.016*
Altitude	-0.914	-0.406	0.315	0.001***

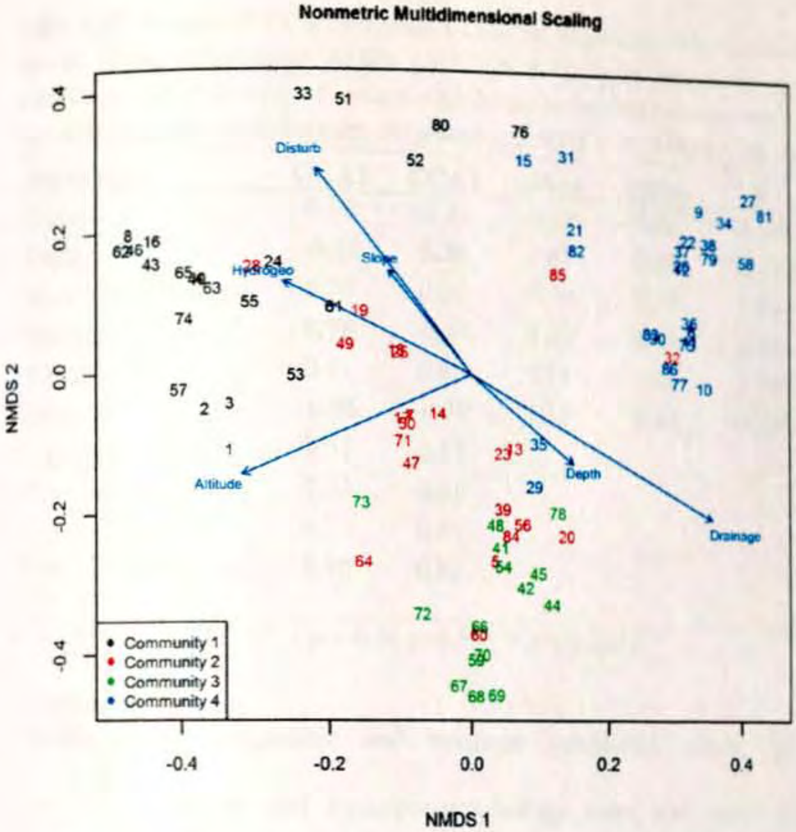


Figure 1.16. Non-metric Multidimensional Scaling (NMDS) diagram of plots of Fincha'a-Chomen Marsh vegetation grouped by community type (Communities 1 to 4). Vectors represent environmental variables: depth, hydrogeomorphology, drainage, disturbance, slope and altitude.

4.3.4.2. Canonical Correspondence Analysis (CCA)

Species and plots ordination in the space defined by the first two CCA axes is shown in Figures 4.17a and 4.17b. Results of CCA showed that six of the environmental factors such as water depth, drainage, disturbance, hydrogeomorphology, altitude and slope) had significant effect on the distribution of wetland vegetation groups. The first and the second axes explained 33% and 21%, of the variance, respectively (Table 4.12). The two axes together explained 54% of the total variation (Table 4.12).

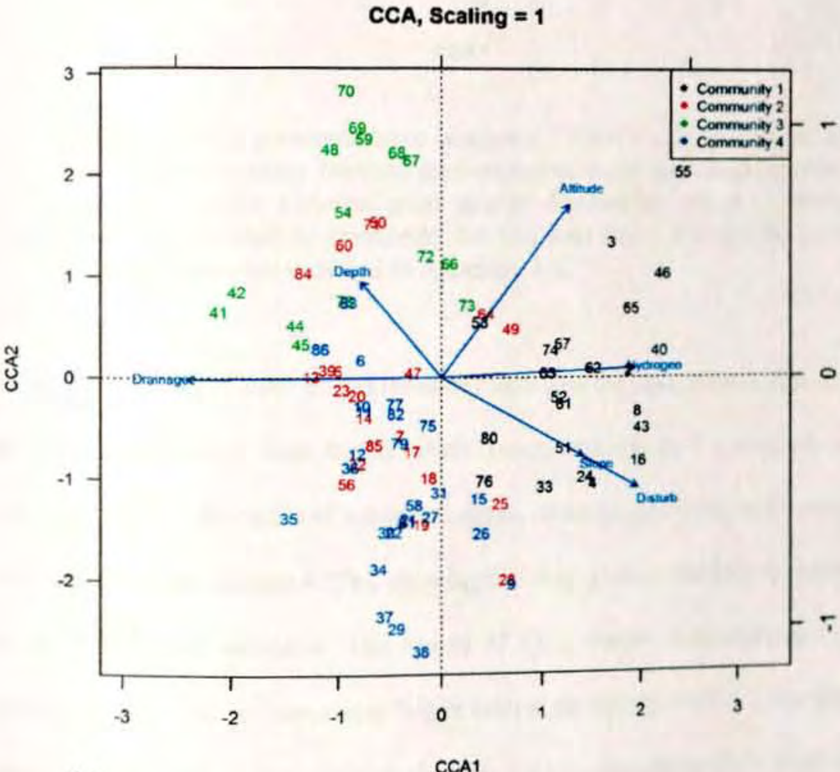
Table 4.12: Results of CCA of Fincha'a-Chomen vegetation data. Canonical coefficients from the best-fit multiple regression models (ANOVA test), biplot scores for the constraining variables, eigenvalues and proportion of variances explained by the first two axes were indicated. Factors values that differed significantly between the groups according to an ANOVA are shown in bold.

Variables	CCA1	CCA2	SSqs	MSqs	F	R2	Pr(>F)
Slope	**0.56**	-0.32	0.51	0.51	1.58	0.02	0.05*
Depth	-0.31	**0.38**	0.67	0.67	2.11	0.02	0.01**
Hydrogeomorphlogy	**0.78**	0.04	0.39	0.39	1.23	0.01	0.05*
Disturb	**0.78**	-0.44	0.91	0.91	2.83	0.03	0.01**
Altitude	0.51	**0.68**	1.21	1.21	3.76	0.03	0.01**
Drainage	**-0.96**	-0.01	3.53	3.53	11.04	0.11	0.01**
Eigenvalues	0.53	0.33					
% variance	0.33	0.21					
Cumulative %	0.33	0.54					
Species enviroment correlations	0.90	0.82					

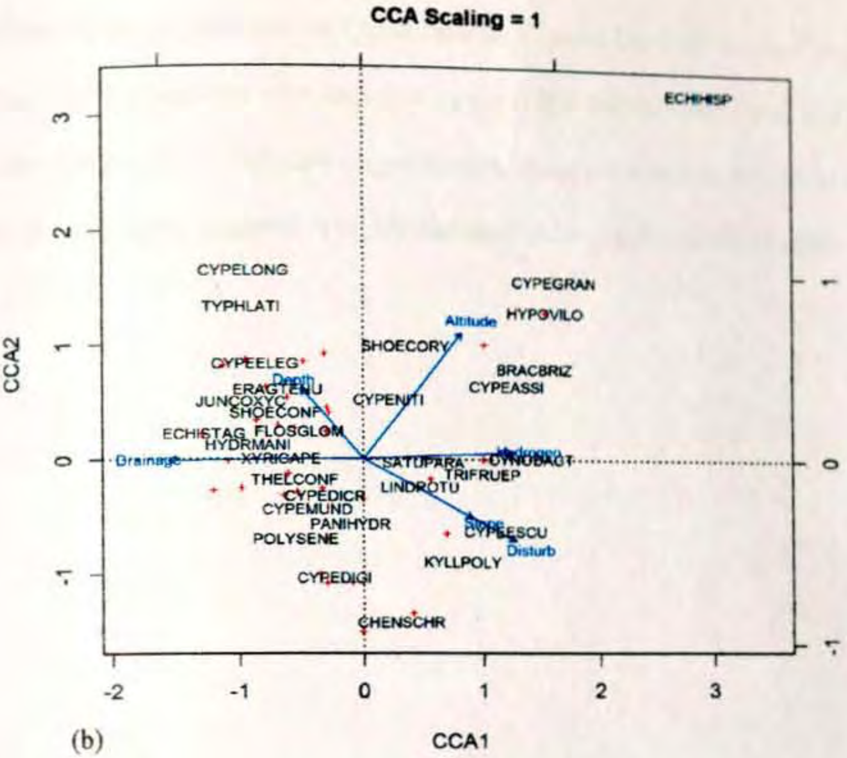
(* = 0.01 < p < 0.05, ** = p < 0.01 and *** = p < 0.001).

Depending on topographic and landform conditions, water depth, slope, drainage, disturbance, altitude and hydrogeomorphology were the main operatiing factors that governed the plant species composition and community distribution in the Fincha'a-Chomen wetlands. The first axis extracted by the analysis was closely related to drainage, hydrogeomorphology and disturbance as indicated by biplot scores of -0.96, 0.78 and 0.78, respectively (Table 4.12). The second axis was more closely related to water depth (0.38) and altitude (0.68) (Table 4.12). The first axis was associated with increasing slope, hydrogeomorphology, disturbance and altitude but with decreasing water depth and drainage.

Disturbance, water depth and hydrogeomorphology differentiated *Lindernia rotundata-Trifolium rueppellianum-Cynodon aethiopicus* community from *Schoenoplectus corymbosus-Cyperus latifolius* community type. Community type one which consisted of terrestrial species most commonly occured in highly disturbed areas along low lying landscape with well drained or somewhat excessively drained soils and terrestrial landscape with water retaining capacity. It was associated with decreasing water level and moderate to steep slope gradient. Plant community type three (*Schoenoplectus corymbosus-Cyperus latifolius*) mainly occurred in areas with higher water level, poor drainage and least disturbance. It was nearly or mainly flat at plot location and surrounding landscape. This community type most commonly occured in waterlogged areas characterized by presence of standing or flowing water permanently or most of the year, open water body and permanently flooded with wetland dependent vegetation distribution. Community types two (*Cyperus dichroostachyus*) and four (*Panicum hygrocharis*) were composed of poorly or very poorly drained levees and associated with decreasing range of altitude. Altitude was a strong factor differentiating this group from all the others.



(a)



(b)

Figure 4.17: Canonical correspondence analysis (CCA) of Fincha`a-Chomen vegetation data. (a) Depicts the relationships between the community types and environmental variables, (b) shows the relationships between plant species distribution and environmental variables. Species were abbreviated by combining the first four letters from generic names and specific epithets (species data were provided in Appendix 1c).

CCA of the species (Figure 4.17b) revealed essentially the same pattern with plots ordination, but plant communities were less distinctly recognized due to the presence of species that might tolerate a wider range of habitat condition. Most species occur at the origin of the CCA ordination diagram (Figure 4.17b), showing that they grow in habitats of moderate values of all the parameters measured. The results of CCA clearly demonstrated the relationship between species and environmental factors such as altitude ($p < 0.01$), water depth ($p < 0.01$), drainage ($p < 0.01$), hydrogeomorphology ($p < 0.05$), disturbance ($p < 0.01$) and slope ($p < 0.05$). The species-environment correlations with the first and second axes were 0.90 and 0.82, respectively (Table 4.12). The first two axes accounted for 54 % of the variation. The wetland dependent plant species *Typha latifolus*, *Cyperus longibracteatus*, *C. elegantulus* and *Schoenoplectus confusus* were indicated on upper left side associated with high water depth. *Cynodon aethiopicus*, *Trifolium rueppellianum*, *Cyperus esculentus* and *Lindernia rotundata* were predominantly occurred in highly disturbed areas with less moisture gradient.

4.4. Dabus Marsh

4.4.1. Floristic Composition

A total of one hundred thirty plant species were identified from Dabus Marsh (Appendix 1d). The species belong to 97 genera and 40 families. Only four families (Cyperaceae, Poaceae, Asteraceae and Fabaceae) account about 60 % of the total proportion (Figure 4.18). Poaceae was the family with the highest number of plant species (19%) followed by the family Cyperaceae (12%), Fabaceae (11%) and Asteraceae (8%) of the total. Herbs/forbs occupied the highest floristic composition followed by sedges and graminoids and shrubs.

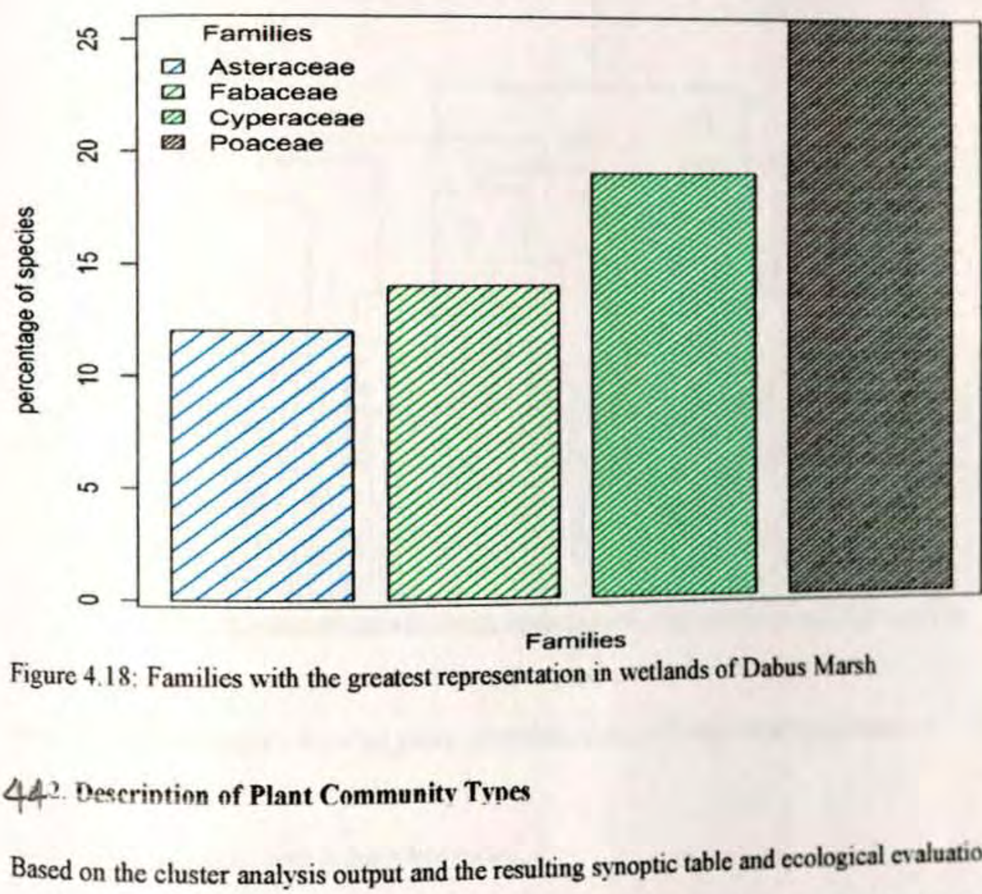


Figure 4.18: Families with the greatest representation in wetlands of Dabus Marsh

4.4.2. Description of Plant Community Types

Based on the cluster analysis output and the resulting synoptic table and ecological evaluation in the field, four plant community types were identified between 1.0 to 2.0 heights (0.30 - 0.60 dissimilarity levels) of the dendrogram (Figure 4.19). The plant community types were named after the dominant species which occur in each group based on the highest synoptic values of plant species (Table 4.13). Community types, the dominant and sub-dominant species, and the number of relevés they contained and diversity indexes of each community type were given in Table 4.14. Species such as *Cyperus papyrus*, *Cynodon aethiopicus*, *Persicaria senegalensis*, *Thelypteris confluens*, *Commelina diffusa* and *Syzygium guineense* subsp. *macrocarpum* were widely distributed in the Dabus wetland and had the high frequency. Each of these species occurred in more than 11.6% of the quadrats.

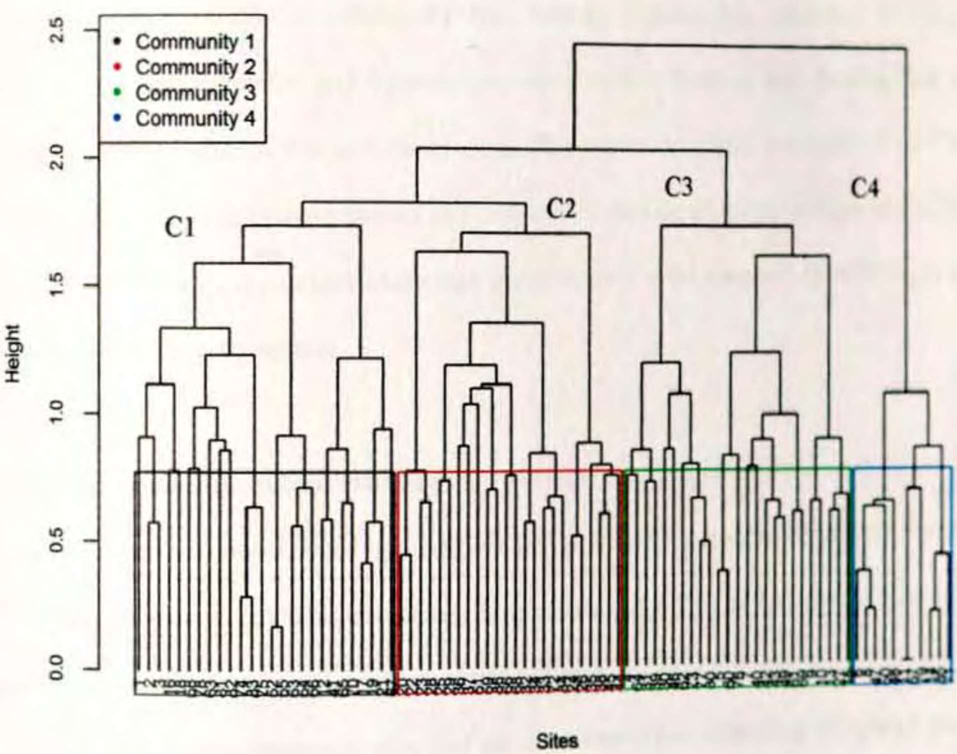


Figure 4.19: Dendrogram showing plant community types of Dabus Marsh vegetation.

Each plant community type is described below.

1. *Cyperus dichroostachyus-Persicaria senegalensis* community type: This community type was very rich in species and dominanted by *Cyperus dichroostachyus* and *Persicaria* *senegalensis*. The subdominant species in this community type include *Cynodon aethiopicus*, *Solanum incanum*, *Guizotia scabra* and *Digitaria ciliaris*. This community type consisted of 30% of the stands. Most of the plants in this community type were emergent macrophytes. This community type had floristic composition largely dominated by sedges with some forbs and grasses.

2. ***Eriochloa fatmensis-Cyperus latifolius* community type:** Dominant species of this community type were *Eriochloa fatmensis* and *Cyperus latifolius* (Appendix 5). The subdominant species of this community type include *Echinochloa stagnina*, *Persicaria decipiens*, *Leersia hexandra* and *Cyperus papyrus*. No free floating and floating-leaf and submersed plants occur in this community type. This community type consisted of 12.7% of the stands. The floristic composition of this community include of forbs, grasses and sedges. This plant community type experiences high pressure from anthropogenic activity especially from burning during dry season.

3. ***Syzygium guineense* subsp. *macrocarpum-Vernonia auriculifera* community type:** This community type was dominanted by *Syzygium guineense* subsp. *macrocarpum* and *Vernonia auriculifera* (Figure 4.20). This community type consists of 27.9% of the stands. Most of the plants in this community type were emergent macrophytes except *Nymphaea nouchali* and *Pistia stratiotes*. This community type had species composition consisting of upland species as followed by some sedges, forbs and grasses. It was found along the edges of wetlands as patches at different distances and was places where spring water occurs.

Figure 4.20: *Syzygium guineense* subsp. *macrocarpum* community type from Dabus wetland

4. *Cyperus papyrus* community type: *Cyperus papyrus* was the most common and dominant hydrophytic plant community type (Figure 4.21) in the study area. It was dominanted by *Cyperus papyrus*. The subdominant species of this community type include *Thelypteris confluens*, *Persicaria decipiens* and *Bidens ternata*. This community type consisted of 29% of the stands. All the species in this community type were emergent macrophytes except *Nymphaea lotus*. The floristic composition of this community type consisted mainly of forbs followed by few sedges and grasses.

Figure 4.21: *Cyperus papyrus* community type from Dabus Mrsh

Table 4.13: Synoptic Table of Dabus marsh showing mean cover values of species within clus

Species	Community types			
	1	2	3	4
Achyranthes aspera	0.000	0.000	0.880	0.000
Achyrospermum schimperi	0.192	0.208	0.000	0.000
Ascolepis eriocauloides	0.000	0.542	0.000	0.000
Bidens pilosa	0.654	0.000	0.000	0.000
Bidens ternata	0.000	0.417	0.000	1.364
Brachiaria brizantha	0.192	0.000	0.000	0.000
Brachiaria pubescence	0.346	0.000	0.000	0.000
Buchnera capitata	0.000	0.000	0.000	0.455
Carex bequaertii	0.192	0.000	0.000	0.000
Carex monostachya	0.000	0.250	0.000	0.000
Chenopodiuim schroderianum	0.192	0.000	0.240	0.000
Commelina diffusa	0.385	0.875	0.560	0.091
Crassocephalum rubens	0.231	0.125	0.000	0.000
Cynodon aethiopicus	2.039	0.000	0.520	0.000
Cyperus atroviridis	0.231	0.000	0.000	0.000
Cyperus dichroostachyus	**2.154**	0.000	0.280	0.000
Cyperus digitatus	0.231	0.292	0.000	0.000
Cyperus dives	0.000	0.000	0.240	0.000
Cyperus fischerianus	0.462	0.250	0.000	0.000
Cyperus flavescens	0.000	0.208	0.000	0.000
Cyperus latifolius	0.231	**1.375**	0.000	0.000
Cyperus papyrus	0.000	1.250	0.000	**8.091**

Cyperus sieberianus	0.000	0.250	0.000	0.000
Cyperus triceps	0.000	0.000	0.000	0.455
Cyperus uniolodes	0.000	0.250	0.000	0.000
Digitaria ciliaris	1.692	0.000	0.000	0.727
Dracaena steudneri	0.000	0.000	0.520	0.000
Echinochloa rotundiflora	0.000	0.583	0.000	0.000
Echinochloa stagnina	0.269	1.333	0.000	0.000
Echinops amplexicaulis	0.423	0.000	1.240	0.000
Echinops hispidus	0.000	0.208	1.480	0.000
Eleocharis acutangula	0.885	0.250	0.000	0.000
Eleusine coracana	0.269	0.000	0.000	0.000
Eragrostis botryodes	0.269	0.000	0.000	0.000
Eriochloa fatmensis	0.000	**2.917**	0.200	0.000
Eriochloa pyramdalis	0.000	0.000	0.240	0.000
Euclea divinorum	0.000	0.000	0.520	0.000
Ficus sur	0.000	0.000	1.600	0.000
Ficus sychomorus	0.231	0.000	0.240	0.000
Ficus vasta	0.000	0.667	0.000	0.000
Floscopa glomerata	0.192	0.708	0.000	0.000
Galiniera coffeoides	0.000	0.292	0.000	0.000
Galinsoga quadriradiata	0.000	0.000	0.280	0.000
Grewia mollis	0.885	0.000	0.160	0.000
Guizotia scabra	0.423	0.000	0.000	0.000
Habenaria zambesiana	0.423	0.208	0.000	0.000
Hyparrhenia hirta	0.539	0.000	0.000	0.000
Hyparrhenia rufa	0.192	0.000	0.000	0.000
Impatiens aethiopica	0.000	0.208	0.200	0.000
Indigofera spicata	0.000	0.250	0.000	0.000
Ipomea purpurea	0.000	0.250	0.000	0.000
Isolepis costata	0.000	0.625	0.000	0.000
Keetia zanzibarica	0.000	0.000	0.200	0.000
Kohautia coccinea	0.000	0.000	0.320	0.000
Lannea fruitcosa	0.000	0.000	0.000	0.182
Leersia hexandra	0.269	1.583	0.000	0.546
Loudetia arundinacea	0.000	0.500	0.000	0.000
Ludwigia abyssinica	0.000	0.250	0.000	0.000
Maesa Lanceolata	0.000	0.375	0.000	0.000
Millettia ferruginea	0.000	0.000	0.400	0.000
Nymphaea nouchali	0.000	0.000	1.080	0.000
Nymphaea lotus	0.231	0.542	0.000	0.364
Panicum maximum	0.000	0.208	0.000	0.000
Panicum pusillum	0.539	0.000	0.000	0.909
Paspalum scrobiculatum	0.192	0.000	0.000	0.000
Pennisetum polystachion	0.231	0.000	0.200	0.000

Pennisetum trachyphyllum	0.000	0.792	0.000	0.000
Pennisetum unisetum	0.000	0.417	0.280	0.000
Smitia eliotii	0.000	0.000	0.000	0.455
Persicaria senegalensis	**2.115**	0.000	0.000	0.154
Persicaria decipiens	0.423	1.667	0.200	2.273
Phoenix reclinata	0.923	0.000	0.000	0.000
Pistia stratiotes	0.192	0.000	1.400	0.000
Plantago lanceolata	0.000	0.125	0.000	0.000
Plectranthus punctatus	0.231	0.000	0.000	0.000
Polygonum amphibium	0.385	0.250	0.280	0.120
Polygonum salicifolium	0.000	0.250	0.000	0.000
Polygonum senegalensis	0.423	0.000	0.000	0.000
Potamogeton pucillus	0.115	1.000	0.000	0.000
Pseudognaphalium luteo-album	0.115	0.042	0.040	0.000
Pycnocycla ledermmanii	0.000	0.208	0.000	0.000
Ranunculus multifidus	0.923	0.292	0.000	0.000
Rubus stuedneri	0.269	0.000	0.455	0.000
Sacciolepis africana	0.000	0.167	0.440	0.000
Satureja paradoxa	0.308	0.000	0.440	0.000
Satyrium brachypetalum	0.000	0.000	0.200	0.000
Scleria hispidula	0.269	0.000	0.000	0.000
Senna obtusifolia	0.000	0.000	0.320	0.000
Sesbania dummeri	0.000	0.583	0.000	0.000
Smithia elliotii	0.000	0.000	0.000	0.455
Solanum incanum	0.231	0.000	0.000	0.000
Sorghum purpureo-sericeum	0.192	0.167	0.200	0.000
Stellaria media	0.000	0.000	0.280	0.000
Sterespermum kunthianum	0.000	0.000	0.280	0.000
Syzygium guineense subsp. *macrocarpum*	0.000	0.250	**2.440**	1.091
Thelypteris confluens	0.000	0.917	0.240	2.455
Trifolium rueppellianum	0.769	0.000	0.280	0.000
Tristemma mauritianum	0.385	0.000	0.400	0.000
Triumfeta pilosa	0.000	0.000	0.080	0.000
Triumfeta rhomoidea	0.000	0.000	0.280	0.000
Urtica simensis	0.000	0.000	0.520	0.000
Verbascum sinaiticum	0.077	0.208	0.280	0.000
Vernonia auriculifera	0.000	0.208	**3.000**	0.000
Vernonia abyssinica	0.346	0.000	0.880	0.000

Table 4.14: Summary of wetland plant community types from Dabus vegetation data.

Agglomerative hierarchical relationships	Plant community types			
	1	2	3	4
Dominant species	*C. dichroostachyus* and *Persicaria senegalensis*	*Eriochloa fatmensis* and *Cyperus latifolius*	*Syzygium guineense* subsp. *macrocarpum* and *Vernonia. auriculifera*	*Cyperus papyrus*
Mean cover	2.15 and 2.12	1.92 and 1.38	2.44 and 3.00	8.09
Sub-dominant species	*Cynodon aethiopicus, Solanum incanum, Guizotia scabra* and *Digitaria ciliaris*	*E. stagnina, P. decipiens, L. hexandra* and *C. papyrus*	*Ficus sur* and *Echinops amplexicaulis*	*T. confluens, P. decipiens* and *B. ternata*
Shannon diversity index	3.59	3.60	3.37	2.16
Shannon evenness	0.91	0.92	0.89	0.76
Richness	52	50	44	17
No of quadrats	11	25	24	26

4.4.3. Diversity of Plant Community Types

The Shannon-Wiener Diversity computed for the plant community types (Table 4.14) showed that community types one (*Cyperus dichroostachyus-Persicaria senegalensis*) and two (*Eriochloa fatmensis-Cyperus latifolius*) had the highest diversity and the highest eveness. On the other hand, community type four (*Cyperus papyrus*) which was observed to be pristine and in natural state had the least Shannon diversity and evenness indices and was the least in species richness. Releves dominated by one or two species present low diversity, in comparison to those characterized by the coexistence of many species, hence the community *Cyperus papyrus* showed the least diversity indices. This community type occurred in frequently flooded and often waterlogged areas. The evenness index provides information about species distribution and indicates whether the high diversity of a plant community is due to the presence of many species with different abundances or to a smaller number of species with a more homogeneous distribution, and therefore shows different pattern. *Cyperus papyrus* community type also presented the lowest value of evenness index, i.e., it had a smaller number of species with a more homogeneous distribution.

4.4.4. Environmental Gradients Influencing Wetland Plant Communities

4.4.4.1. Multivariate Non-metric Multidimensional Scaling (NMDS)

Plant community types were clearly separated from one another in the ordination space (Figure 4.22). Community type four (*Cyperus papyrus*) was highly correlated with water depth (Table 4.15, r^2=0.449, p=0.001) and was clearly separated from others being situated on far left side. Community type one (*Cyperus dichroostachyus-Persicaria senegalensis*) was positively correlated with disturbance (Table 4.15, r^2=0.266, p=0.001) where as community three (*Syzygium guineense* subsp. *macrocarpum-Vernonia auriculifera*) was positively correlated with hydrogeomorphology (Table 4.15, r^2=0.349, p=0.001).

Table 4.15. Pearson (r^2) correlations of Nonmetric Multidimensional Scaling ordination axes with environmental variables of Dabus Marsh vegetation. Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1, P values based on 999 permutations

Vectors	NMDS1	NMDS2	r^2	Pr(>r)
Depth	-0.967	-0.255	0.449	0.001***
Hydrogeo	0.919	0.394	0.349	0.001***
Drainage	-0.926	-0.379	0.304	0.001***
Disturb	0.960	-0.281	0.266	0.001***
Slope	0.888	0.460	0.225	0.001***
Altitude	0.661	0.750	0.045	0.142

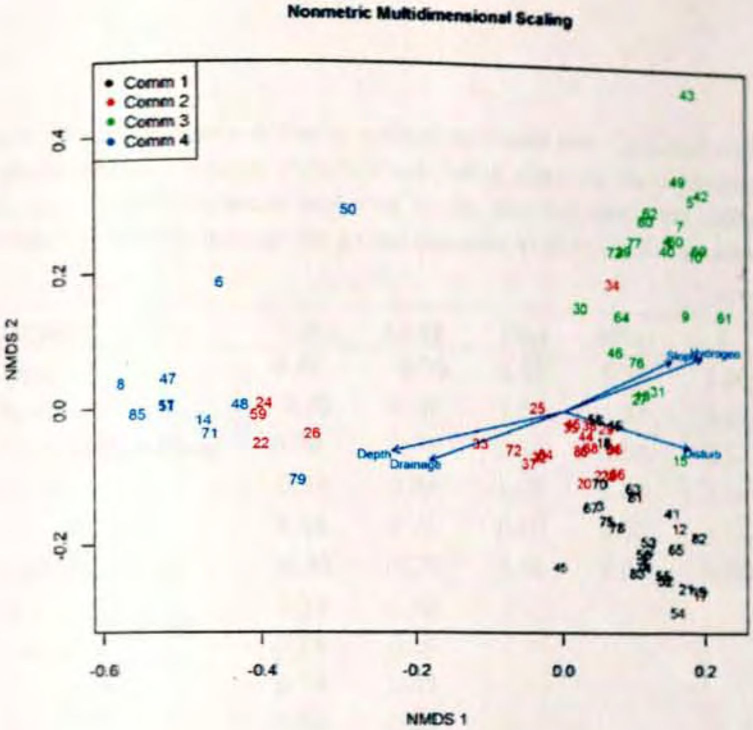


Figure 4.22. Non-metric Multidimensional Scaling (NMDS) diagram of plots of Dabus Marsh vegetation grouped by community type (communities 1 to 4). Vectors represent environmental variables: depth, hydrogeomorphology, drainage, disturbance and slope.

4.4.4.2. Canonical Correspondence Analysis (CCA)

Although the two axes extracted by CCA analysis together explained 43% of the total variation (Table 4.16), analyses by ANOVA showed that environmental factors such as water depth, slope, drainage, disturbance, altitude and hydrogeomorphology were significantly ($p < 0.05$) related to the floristic composition of the plant community types. Species and plots ordination in the space defined by the first two CCA axes was given in Figures 4.23 (a) and (b). The proportion of variances explained by these axes was 24 % and 19 %, respectively (Table 4.16).

Table 4.16: CCA results of Dabus wetland vegetation data. Canonical coefficients from the best-fit multiple regression models (ANOVA test), biplot scores for the constraining variables, eigenvalues and proportion of variances explained by the first two axes were indicated. Factors values that differed significantly between the groups according to an ANOVA are shown in bold.

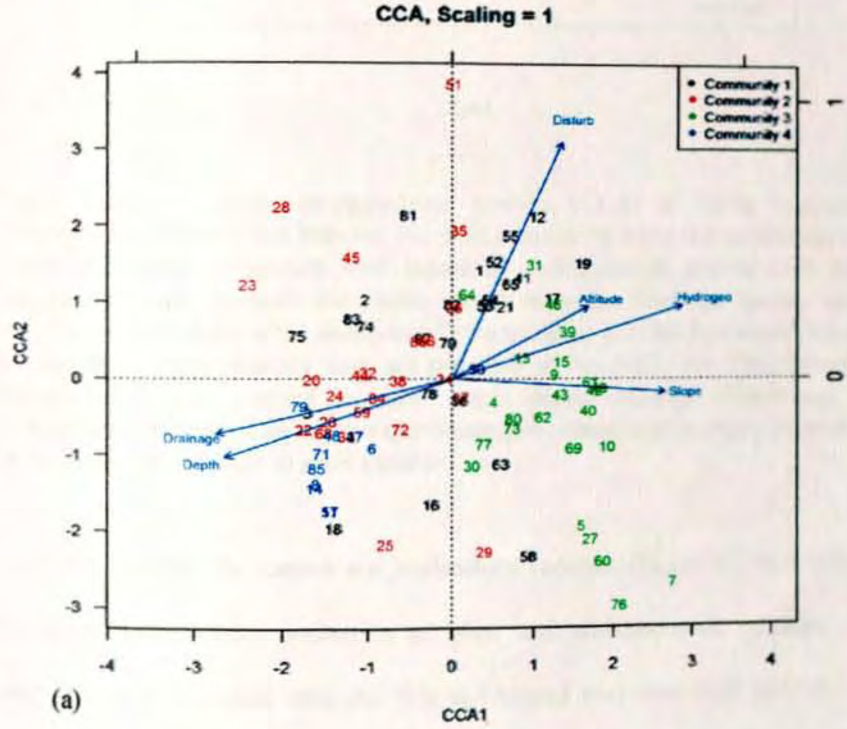
Variables	CCA1	CCA2	SSqs	MSqs	F	R^2	Pr(>F)
Slope	**0.72**	-0.05	0.53	0.53	1.30	0.01	0.03*
Depth	**-0.73**	-0.28	1.37	1.37	3.37	0.04	0.01**
Hydrogeomorphlogy	**0.78**	0.26	0.64	0.64	1.57	0.02	0.04*
Disturb	0.37	**0.84**	1.08	1.08	2.64	0.03	0.01**
Altitude	**0.46**	0.26	0.60	0.60	1.47	0.02	0.05*
Drainage	**-0.75**	-0.20	2.08	2.08	5.10	0.05	0.01**
Eigenvalues	0.55	0.42					
% variance	0.24	0.19					
Cumulative %	0.24	0.43					
Species env. corr.	0.88	0.83					

(. = $p < 0.1$, * = $0.01 < p < 0.05$, ** = $p < 0.01$ and *** = $p < 0.001$).

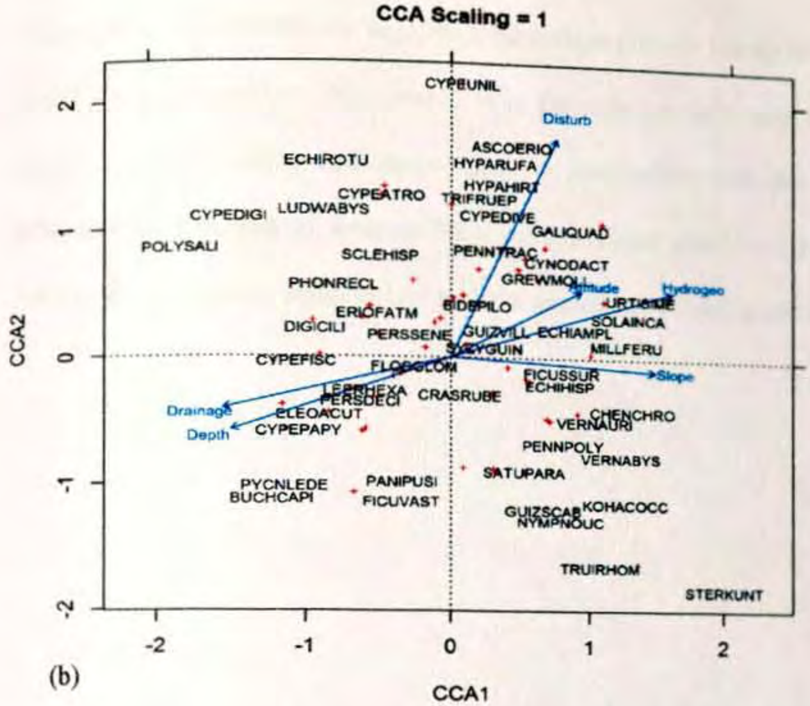
The first axis extracted by the analysis was closely related to the water depth, slope, drainage, altitude and hydrogeomorphology. The second axis was highly correlated to disturbance. The second axis was mainly associated with increasing disturbance but with decreasing water depth, slope and drainage.

Hydrogemorphology and slope were most significant factors that differentiated community three (*Syzygium guineense* subsp. *macrocarpum-Vernonia auriculifera*) from community type four (*Cyperus papyrus*) and community type two (*Eriochloa fatmensis-Cyperus latifolius*). Community type four (*Cyperus papyrus*) was associated with high water level and very poorly drained areas. These groups most commonly occurred in areas characterized by presence of standing or flowing water permanently or most of the year, open water body and permanently flooded with uneven vegetation distribution and mainly nearly flat with no slope. Community two (*Eriochloa fatmensis-Cyperus latifolius*) was associated to well or with relatively well drained areas. These groups most commonly occurred in areas characterized by low lying relativly less wet terrestrial landscape.

Disturbance type was a strong factor that differentiated community one (*Cyperus dichroostachyus-Persicaria senegalensis*) from community three (*Syzygium guineense* subsp. *macrocarpum-Vernonia auriculifera*) and four (*Cyperus papyrus*). Community type one (*Cyperus dichroostachyus-Persicaria senegalensis*) was associated with area occasionally burnt for livestock grazing. Community type three (*Syzygium guineense* subsp. *macrocarpum-Vernonia auriculifera*) was related to mainly nearly flat areas with no slope.



(a)



(b)

Figure 4.23: Canonical correspondence analysis (CCA) of Dabus vegetation data. (a) Illustrates the relationships between the plant community types and environmental factors. (b) Shows placement of species with regard to environmental factors. Only higher priority species with high variances are visible and all other less dominant species are indicated by red plus signs. Species were abbreviated by combining the first four letters from generic names and specific epithets (species data are provided in Appendix 1d). Environmental attributes represented by the vectors included: water depth, drainage, disturbance, altitude and hydrogeomorphology. The vectors representing environmental gradients point in the direction of the most rapid change in each variable.

CCA ordination of the species and explanatory variables (Figure 4.23b) revealed essentially the same pattern with ordination of plots and environmental variables. The species-environment correlations with the first and second axes were 0.88 and 0.83, respectively (Table 4.16). The first two axes accounted for 43 % of the variation.

The plant species *Solanum incanum*, *Millettia ferruginea*, *Vernonia auriculifera* and *Vernonia abyssinica* had marked positive relationships with the first axis (related to the slope and hydrogeomorphology, whereas *Polygonum salicifolium*, *Cyperus papyrus* and *Cyperus* *fischerianus* had significantly negative relationships (closely related to drainage and water depth). *Cyperus uniolodes*, *Hyparrhenia rufa*, *Trifolium rueppellianum*, *Cynodon aethiopicus* and *Ludwigia abyssinica* had marked positive relationships with the second axis (highly influenced by disturbance), whereas *Ficus vasta*, *Panicum pusillum* and *Nymphaea nouchali* had significant negative relationships with the second axis (found in undisturbed areas).

CHAPTER FIVE

5. DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1. Discussion

5.1.1. Spatial Variations in Floristic Composition and Diversity

A total of 302 vascular plant species belonging to 194 genera and 72 families were identified from all the studied wetlands (Appendix 1a-1d). Of the total families, eleven (15%) were commonly occurring in all the wetlands. These include Amaranthaceae, Asteraceae, Commelinaceae, Cyperaceae, Euphorbiaceae, Fabaceae, Lamiaceae, Nymphaeaceae, Onagraceae, Poaceae and Solanaceae. Fifteen genera (8%) were common to all the wetlands. These include *Cyperus* (Cyperaceae), *Achyranthes* (Amaranthaceae), *Acacia* (Fabaceae), *Solanum* (Solanaceae), *Commelina* (Commelinaceae), *Leersia* (Poaceae), *Cynodon* (Poaceae), *Aeschynomene* (Fabaceae), *Echinochloa* (Poaceae), *Eragrostis* (Poaceae), *Guizotia* (Asteraceae), *Ludwigia* (Onagraceae), *Nymphaea* (Nymphaeaceae), *Plecthrantus* (Lamiaceae) and *Sesbania* (Fabaceae). Only six species (2%) were commonly occurring in the four wetlands. These include *Cyperus latifolius*, *Achyranthes aspera*, *Solanum incanum*, *Commelina diffusa*, *Leersia hexandra* and *Cynodon aethiopicus*.

Poaceae was the family with the highest number of species in all wetlands except Cyperaceae which had the highest number of species in Fincha'a-Chomen wetlands (Figure 5.1). The families Xyridaceae, Juncaceae, Hypoxidaceae, Hypericaceae, Gentianaceae and Eriocaulaceae were recorded only from Fincha'a-Chomen wetlands. The occurrence of high number of unique families at Fincha'a-Chomen site would seem to be due to the higher altitude with its ambient temperature and high rain fall.

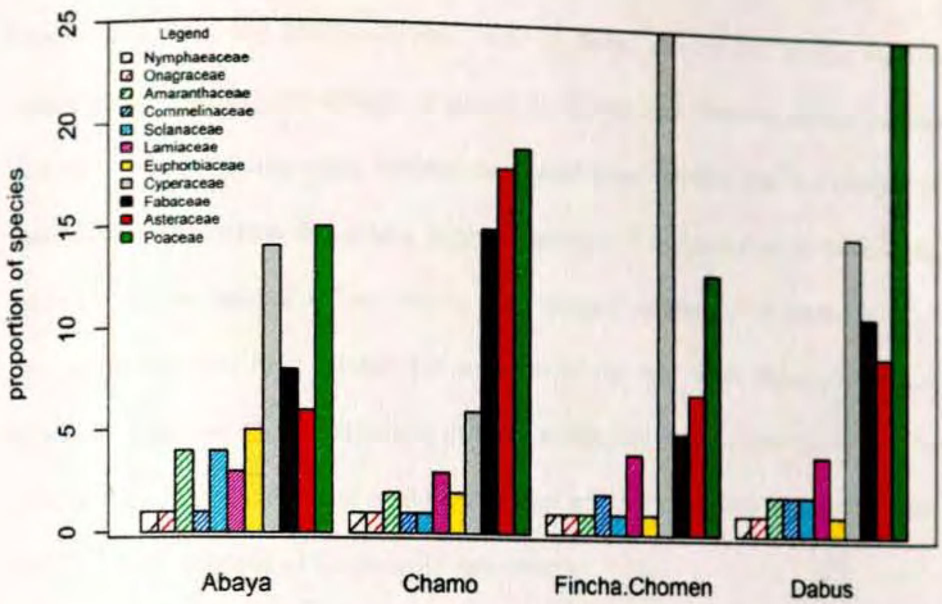


Figure 5.1: Families common to all sites and proportion of species they contain. Y-axis: proportion of species contributed by each family common to all sites, X-axis: Families and study sites. Families common to all sites include: Amaranthaceae, Asteraceae, Commelinaceae, Cyperaceae, Euphorbiaceae, Fabaceae, Lamiaceae, Nymphaeaceae, Onagraceae, Poaceae and Solanaceae.

The floristic composition of wetlands changes from time to time and place to place and species diversity contracts and expands with fluctuating water levels. Floristic diversity comparisons are problematic because they were done at different spatial and temporal scales. Nonetheless, despite problems with direct floristic comparisons among wetlands, comparisons are useful for documenting changes in the vegetation of the wetland flora and for enhancing an understanding of the effects of similar environmental and anthropogenic influences on wetlands with different characteristics.

Plant species collected from the study areas belong to different growth forms such as forbs, sedges, shrubs and ferns and show clear zonation patterns (shrub, wet meadow, marsh and aquatic zones). Forbs occupied the highest floristic composition followed by grasses, sedges and shrubs in all survey sites (Figure 5.2). This was more pronounced in wetlands of Lake

Chamo. In Dabus and Fincha-Chomen, next to forbs, grasses and sedges were the most common components, respectively (Figure 5.2). Dabus and Fincha-Chomen wetlands were also very rich in hydrophytes, wetland dependent plant species that are tolerant to a high water table. The reason for a very high percentage of hydrophytes in these areas can be attributed to the habitat characteristics, waterlogged seasonally or permanently for long growing season and high rainfall but wetlands of the two lakes experience water-logging usually at rainy season. In addition to its highest diversity at all taxonomic levels, Dabus was also an important reservoir of relatively highest number of endemic plants. Hence, Dubus could serve the purpose of biodiversity conservation.

Dominant grass species recorded from the study sites included the annuals *Echinochloa stagnina*, *Echinochloa pyramidalis*, *Eriochloa fatmensis* and *Panicum hygrocharis* and the perennials *Eragrostis tenuifolia*, *Cynodon aethiopicus*, *Leersia hexandra* and *Leptochloa fusca*. Species such as *Cynodon aethiopicus*, *Cyperus articulatus*, *Leersia hexandra*, *Sesbania sesban*, *Solanum incanum*, *Typha angustifolia*, *Cyperus latifolius and Aeschynomene elaphroxylon* were the species with high frequency. Each of these species occurred in more than ten percent of the quadrats. The fern, *Thelypteris confluens* was widespread across all sites during both wet and dry seasons. Species such as *Cynodon aethiopicus* were more dominant in the over-grazed and highly degraded parts of the wetlands. Other frequently occurring hydrophytic species included members of Cyperaceae and Typhaceae. A scattered shrub layer mostly consisting of *Kotschya africana*, *Vernonia auriculifera* and *Solanum incanum* were recorded predominantly in the Dabus site during the dry season survey. Herbaceous species belonging to Asteraceae and Fabaceae were also prevalent particularly during the wet season surveys in all survey areas.

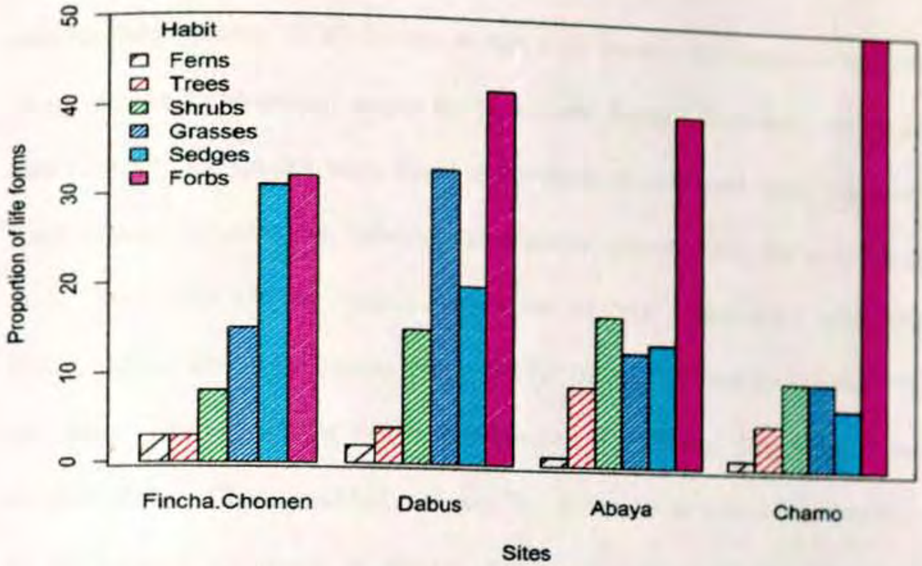


Figure 5.2: Proportion of different life forms recorded from the study sites. X-axis: study sites. Y-axis: proportion of different growth forms

Most of the plants in the wetlands under investigation were emergent macrophytes except for *Potamogeton pucillus* (submerged), *Wolffia arrhiza,* and *Spirodela polyrrhiza* (free floating) and *Pistia stratiotes. Echhornia crassipes. Nymphaea nouchali* . and *Nymphaea lotus* (floating-leaf plants). Emergent macrophytes are plants which anchors with their roots in the soil while the stem and the leaves emerge above the water surface. The submerged plant has all its parts below the water surface except for the flower which emerge above the water surface. Floating-leaf plants have their leaves floating on the surface of the water while the remaining parts stay below the waters surface. As the water level declined throughout the dry season, the free-floating, floating-leaf and submerged species became less abundant.

Of all the species found in the study areas, seven were endemic (Appendix 1a-1d) (Ensermu Kelbessa, unpublished data; Ensermu Kelbessa, *et al.*, 1992; Vivero *et al.*, 2005). Endemic species included: *Erythrina brucei. Millettia ferruginea. Satureja paradoxa. Ascolepis eriocauloides, Scadoxus nutans, Satyrium aethiopicum* and *Urtica simensis*. All of these were rcorded from Fincha-Chomen and Dabus marshes. This number is lower than the general situation in the country. Of all the species, two were invasive alien species (Appendix 1a-1d). These include: *Eichhornia crassipes* (in Chamo and Abaya Lakes) and *Lantana camara* (in Lake Chamo). Six species were found to be weeds of cultivated lands (Appendix 1a-1d). These include: *Amaranthus hybridus*, *Amaranthus spinosus* and *Echinochloa colona* (in Lakes Chamo and Abaya), *Datura stramonium* (in Lake Abaya and Fincha-Chomen) and *Plantago lanceolata* and *Cyperus esculentus* (in Dabus and Fincha-Chomen). No endemic taxa rather invasive species and weedy species of cultivated land were recorded from wetlands of Lake Chamo and Lake Abaya. The reason for no existence of endemic taxa but for the frequent occurrence of invasive and weedy species and the appearance of plant community types dominated by invasive alien species such as *Eichhornia crassipes* in wetlands of Lake Chamo and Lake Abaya might be due to continuous anthropogenic pressures on the areas.

Comparing the floristic diversity between wetlands (alpha diversity and species turnover or beta diversity sensu Whittaker, 1972), there was a high degree of dissimilarity. The wetlands of Lake Chamo had the lowest species number (88 species), whilst Dabus had the highest alpha diversity (130 species). The Fincha Chomen wetland samples had the lowest species turnover or beta diversity (1.20), whilst the samples of Lake Abaya wetland had the highest beta diversity or species turnover (1.98) (Table 5.1). A high β–diversity index indicates a low level of similarity, while a low beta diversity index shows a high level of similarity. Thus, there was higher similarity or few species differences between samples from Fincha Chomen wetlands but more species differences or lowest similarity between samples from wetlands of Lake Abaya.

Table 5.1: Alpha and beta diversity and the number of communities of wetlands

wetland	Species number	Cluster number	β–diversity between sample plots	β -diversiyty between community types
Abaya	92	5	1.98	0.63
Chamo	88	4	1.47	0.62
Fincha-Chomen	92	4	1.20	0.57
Dabus	130	4	1.86	0.79

However, the relative diversity did not remain constant when considering the taxa at different levels (species, genera and family) (Figure 5.3). For example, Dabus marsh was the richest wetland at all levels (species, genera and family). The high diversity of streamside habitats could reflect seed dispersal along stream corridors of Dabus River. Disturbance in the form of overgrazing can also increase species diversity by opening up growing space and resources for use by colonizing species. Wetlands of Lake Chamo remained the poorest at the family and species level. Drainage for cultivation can affect ground water table and in turn the organic matter content of the soil. Wetlands of Lake Abaya remained the poorest at the genera level. Disturbance in the form of burning, land use types, drainage, pollution, eutrophication or overgrazing can reduce plant species diversity by eliminating disturbance sensitive species (Connell, 1978). Ecological theory (Grime, 1973; Connell, 1978) also predicts important linkages between disturbance frequency and species diversity with more frequently disturbed ecosystems showing high species diversity through creation of increased number of ecological niches or conditions which suit for a wide range of plants or microsites that are prone to colonisation by other species. However, the relationship between disturbance and species diversity is not always linear as there are threshold of disturbance which affect the ability of plants to colonize an area.

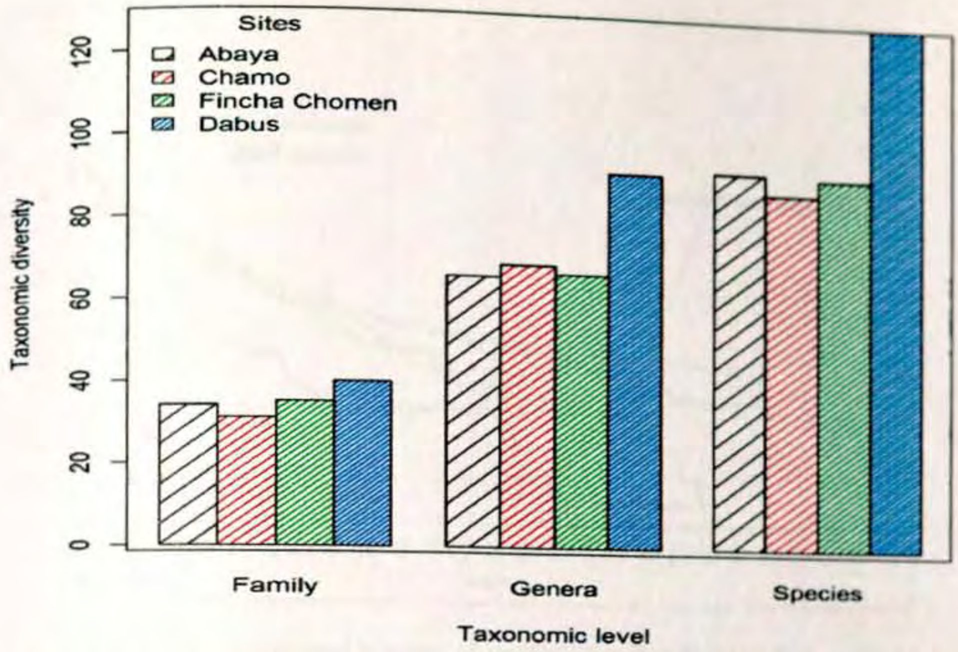


Figure 5.3: Taxonomic diversity profile of the wetlands. X-axis: taxa at different levels (species, genera and family). Y-axis: relative diversity taxa at different levels

Species diversity ordering in terms of species rank abundance (Figure 5.4) shows that the number of rare or less common plant species (species which occurred in few number of sampled plots) were lowest at Chamo wetland and highest at Dabus wetland (Figure 5.4). The numbers of most common species were highest in Lake Abaya wetlands (Figure 5.4). Dabus was relatively the richest and had more even distribution than other sites. *Cyperus articulatus, Cynodon aethiopicus, Leersia hexandra, Solanum incanum* and *Sesbania sesban* were the most abundant species in wetlands of Lake Chamo; *Eichhornia crassipes, Leersia hexandra, Cynodon aethiopicus, Typha angustifolia* and *Aeschynomene elaphroxylon* in Lake Abaya; *Cynodon aethiopicus, Lindernia rotundata, Trifolium rueppellianum* and *Panicum hygrocharis* in Fincha'a-Chomen and *Cyperus papyrus* in Dabus.

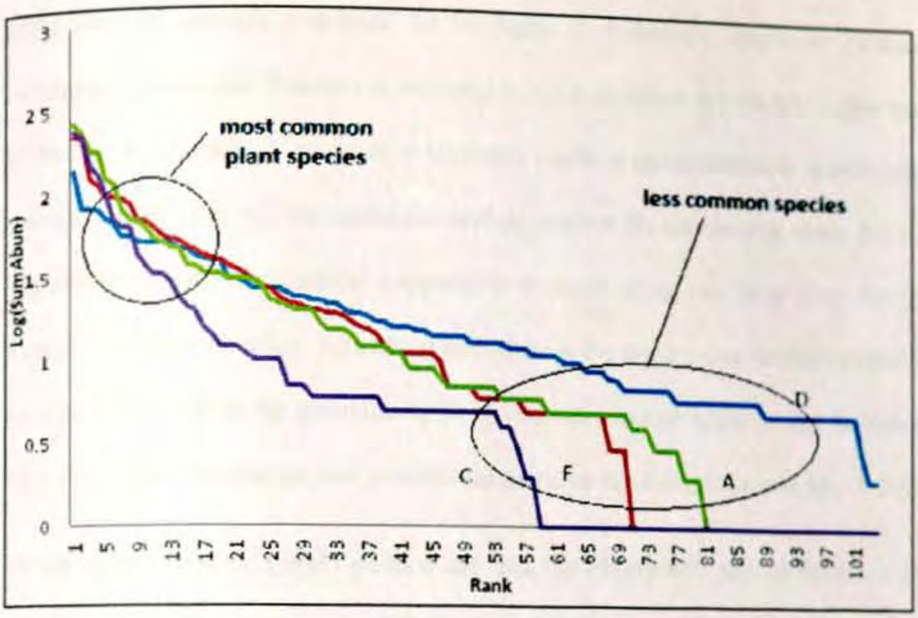


Figure 5.4: Diversity ordering in terms of species rank abundance of four wetlands: Lake Chamo (C), Lake Abaya (A), Fincha'a-Chomen (F) and Dabus (D). X-axis: the abundance rank. Species ranked from most to least abundant. The most abundant species is given rank 1; the second most abundant is 2 and so on. Y-axis: the relative abundance measured on a log scale, this is a measure of species abundance relative to the abundance of other species.

Complementarity assessment revealed compositional similarity in wetland vegetation types of similar proximity and environmental conditions. The result of Sorensen's coefficient of similarity analysis indicated that wetlands associated with the two low land lakes (Lake Chamo and Lake Abaya) and wetlands in the highlands (Fincha'a-Chomen and Dabus) were highly complementary to each other than to any other group, with the former two types being very similar (0.196 and 0.168 Sørensen index, respectively). Thus, wetlands of the two lakes and wetlands of the two marshes had more number of species in common than the other pair of wetlands (Figure 5.5). These consistencies could be partially explained by geographic location and proximity between the related sites. This might be because the chance for seed dispersal between them is limited since wetlands of the southern and western regions are geographically isolated from one another. High similarity of floristic composition in wetlands of the two lakes might also be due to similarity in their natural historic formations. These could also be partially explained by similarity in hydrologic conditions (water depth, hydrogemorphlogy and drainage as indicated by CCA results in this study). Higher similarity of floristic composition of wetlands in highlands might be due to similarity in their proximity, similarity in rrainfall and the catchment landuse types in the surrounding areas. But they had less similar floristic composition compared to wetlands of the two lakes since they are also located far from each other. Altitudinal difference is the major cause for the variation. Other most probable reasons for dissimilarity of species composition might be due to variations in relative moisture conditions, soil particles composition and soil texture and rate of grazing.

Mitsch and Gosselink (1993) pointed out that the distribution and composition of plant species is controlled primarily by differential distribution of hydrologic regimes. A change in elevation would result in channges in the species composition, community and structure of vegetation as a result of greater fluctuation in hydrologic conditions. All the study sites together had very few shared species. In general, the species turnover between sites were high (similarity index less than 0.20), and this indicated that the corresponding habitats heterogeneity increased gradually.

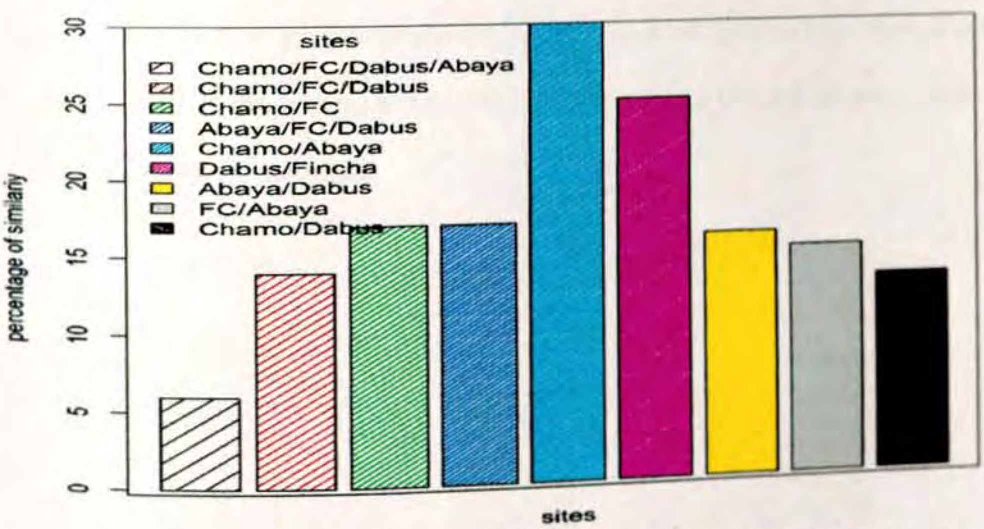


Figure 5.5: Vegetation composition similarity between and among wetlands: Lake Chamo, Lake Abaya, Fincha'a-Chomen (FC) and Dabus.

5.1.2. Seasonal Trends in Floristic Composition and Diversity

The four wetlands differed in taxonomic diversity at all levels in both seasons (Figure 5.6). From wetlands of Lake Chamo, 88 species belonging to 69 genera and 31 families were enumerated in the wet season, while 77 species belonging to 60 genera and 26 families were found in the dry season. From wetlands of Lake Abaya, 92 species belonging to 66 genera and 34 families were enumerated in the wet season and 88 species from 34 families and 63 genera in the dry season. All the species, families and genera in the dry data season from wetlands of Lake Abaya and Chamo also belong to wet season data (Figure 5.6). The greatest number of species was recorded in common from both seasons at wetlands of Lake Abaya (Figure 5.6). Fincha'a Chomen had 92 species from 68 genera and 35 families and 72 species from 55 genera and 32 families in the wet and dry seasons, respectively. Fifty eight species belonging to 31 genera and 46 families were recorded in common from both seasons. One hundred thirty species in 92 genera and 40 families were enumerated in the wet season, while 96 species belonging to 72 genera and 34 families were enumerated in the dry season. Eighty five species belonging to 64 genera and 34 families were recorded in common from both seasons in Dabus. The greatest number of species, genera and families were recorded in both seasons at Dabus marsh (Figure 5.6). This was followed by wetlands of Lake Abaya and Fincha'a-Chomen (Figure 5.6).

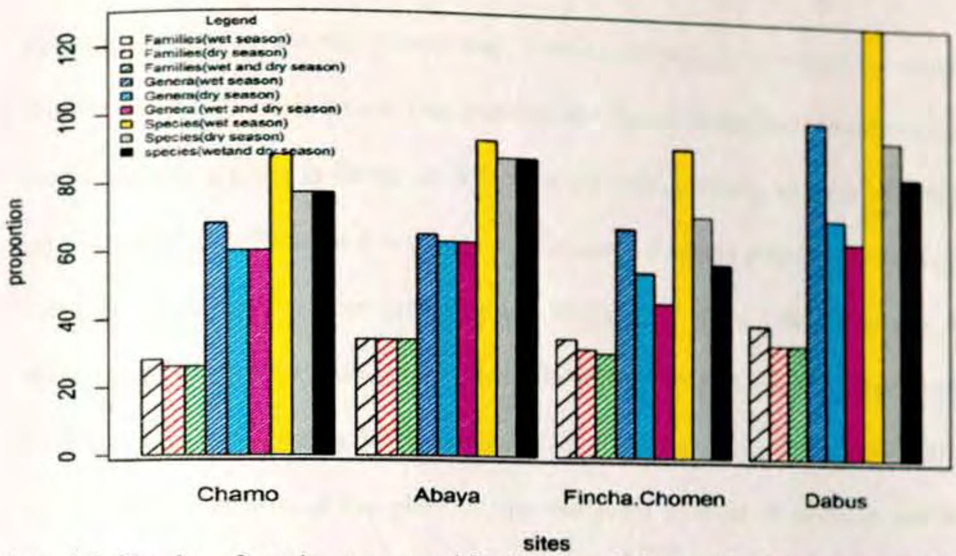


Figure 5.6: Number of species, genera and families recorded per wetland during wet and dry seasons

Each wetland exhibited some seasonal shift in floristic composition and taxonomic diversity. With respect to all levels of taxonomic diversity, the wet season flora tended to be richer than the dry season in all wetlands (Figure 5.6). This was more pronounced in Dabus marsh than in the other three wetlands (Figure 5.6). Its taxonomic diversity decreased from 130 to 96 species, from 101 to 72 genera and from 40 to 34 families in the dry season. Fincha'a-Chomen marsh had also shown a significant reduction in taxonomic diversity from 92 to 72 species from 68 to 55 genera and from 35 to 32 families in the dry season. The reason for the wet season flora richness was the conditions for plant growth, especially for annual species, is better during the wet season rather than during the dry season. The order of floristic richness in the wet season was Dabus marsh > Abaya lake > Fincha'a-Chomen marsh > Chamo lake (Figure 5.6). The order of floristic richness in the dry season was Dabus marsh > Abaya lake > Chamo lake > Fincha'a-Chomen marsh (Figure 5.6).

Microtopographic variation in Dabus and Lake Abaya may contribute to the high plant species richness. High intensity of wetland grazing by livestock and burning in Dabus and

Fincha'a-Chomen in the dry season may have contributed for a significant reduction in diversity at all taxonomic levels. This could be also due to habitat disturbance caused by the intense wildlife grazing in Dabus (as it forms a dry season grazing area for wildlife such as gazelles, hippos, buffaloes and warthogs) and impacts of human activities (intense burning). These are illustrated by photographes taken during field work. Grazing usually removes above ground part of the plant but the possibility for regeneration remains. Grazing results in soil compaction that hinders the circulation of air and water within the air spaces of the soil and this affects growth of the plant. It can also result in input of manures and selective removal of plant species. Species losses occur as a result of habitat loss and fragmentation of ecosystem because of direct human activities, including trampling and collecting. Trampling associated to fishing could be responsible for the lower number of plant species (diversities) encountered at the wetlands (Lake Abaya and Chamo wetlands in particular) in the dry season since only hardy species would survive such activities.

5.1.3. Trends in Plant Communty Types, Diversity and Distribution Pattern

With regard to the vegetation mosaics present in each wetland, the presence of different communities within the wetlands was not very variable (Table 5.2). The number of communities in the wetlands was not correlated with the number of species (Table 5.1). This variability was not only reflected in the number of communities but by the community composition of each wetland. The species turnover between communities were rather high (beta diversity sensu Whittaker being greater than 0.50, Table 5.1), for all sites and this indicated the corresponding habitat heterogeneity increasing gradually. Similar results have been obtained analysing Californian pools at a larger geographic scale (Barbour, 1991). Plant community development in study areas has likely been affected by the lack of environmental heterogeneity. Flinn (2008) pointed out that human-induced disturbances often result in the removal of native vegetation and the elimination of the existing soil structure and microtopographic features that are important for habitat heterogeneity.

From all the study sites, the highest number of plant community types was recorded from wetlands of Lake Abaya during both wet and dry seasons (Table 5.2). Dendrograms showing dry season vegetation clusters was shown in appendix 3. The most important process that is thought to play a vital role in determining the habitat diversity of these wetlands is environmental heterogeneity. Microtopographic variation may also contribute to the high diversity of wetland plant communities in wetlands of Lake Abaya. Connell (1978) pointed out that changes in the environment due to change in landuse type, drainage, eutrophication or overgrazing can alter spatial heterogeneity in plant community composition.

Table 5.2: Summary of Plant community types present in each wetland during both survey periods

Site	Plant community types (Wet period)	Plant community types (Dry period)
L. Chamo	1. *Cyperus articulatus –Cynodon aethiopicus* 2. *Cynodon aethiopicus- Solanum incanum* 3. *Leersia hexandra* 4.*Cyperus articulatus -Typha angustifolia*	1. *Cynodon aethiopicus - Sesbania sesban* 2. *C. aethiopicus - Solanum incanum* 3. *Leersia hexandra* 4. *Cyperus articulatus –T. angustifolia* 5. *Aeschynomene elaphroxylon*
L. Abaya	1. *Cyperus articulatus* 2. *Eichhornia crassipes - Pistia stratiotes* 3. *Cynodon aethiopicus* 4. *T.angustifolia –A. elaphroxylon* 5. *Aeschynomene elaphroxylon*	1. *T. angustifolia – A. elaphroxylon* 2. *C. aethiopicus-Solanum incanum* 3 *E. crassipes - Pistia stratiotes* 4. *Cynodon aethiopicus* 5. *Cyperus articulatus- C. laevigatus* 6. *Aeschynomene elaphroxylon*
Fincha-Chomen	1. *Lindernia rotundata - Trifolium rueppellianum- Cynodon aethiopicus* 2. *Cyperus dichroostachyus* 3. *S. corymbosus - C. latifolius* 4. *Panicum hygrocharis*	1. *C. aethiopicus-Lindernia rotundata* 2. *R. multifidus- Lindernia rotundata* 3. *C. dichroostachyus- T. confluens* 4. *Panicum hygrocharis* 5. *S. confusus –C. latifolius*
Dabus	1. *C. dichroostachyus – P. senegalensis* 2. *Eriochloa fatmensis-Cyperus latifolius* 3. *Syzygium guineense* subsp. *macrocarpum –V. auriculifera* 4. *Cyperus papyrus*	1. *Cynodon aethiopicus* 2. *Syzygium guineense* subsp. *macrocarpum –V. auriculifera* 3. *Cyperus papyrus* 4. *Echinops hispidus- V. auriculifera* 5. *Eriochloa fatmensis- C. papyrus*

Although Dabus experiences critical pressure from burning and grazing activities during dry season, it was partially and relatively pristine with a climax like swamp or marsh community dominated by *Cyperus papyrus*. The most extensive and distinctive plant community in wetlands of Lake Abaya was *Aeschynomene elaphroxylon* and *Typha angustifolia*. Wetlands of Lake Chamo had also the most distinctive plant communities (*Leersia hexandra* and *Cyperus articulatus*). In Fincha-Chomen wetlands, most extensive and distinctive plant community type was *Cyperus dichroostachyus*.

Wetlands of the two lakes had plant community types that were dominated by similar species (*Cyperus articulatus, Cynodon aethiopicus* and *Typha angustifolia*) (Table 5.2). Similarly, wetlands of the two marshes had plant community types that were dominated by similar species (*Cyperus dichroostachyus* and *Cyperus latifolius)* (Table 5.2). Regardless of having some plant species in common, the four wetlands did not have combination of different species that characterize similar plant associations in common for all. Thus, wetlands of the lakes and marshes had no plant community types in common. These could be partially explained by geographic isolation between and among sites. This difference in plant community types between wetlands of the two lakes was probably related to the difference in eutrophication of the lakes. The presence of *Eichhornia crassipes-Pistia stratiotes* community in the wetlands of Lake Abaya seems to confirm strong human activities in the study area. Plant communities reflect a recurring assemblage of plant species of characteristic composition and structure, growing in an area of essentially similar environmental conditions and land use history (Shipley and Keddy, 1987).

Variation in plant distribution, abundance, and floristic composition of wetland plant communities could be associated primarily with the variation in geographic location, hydrologic condition, patterns and degree of disturbance, various catchment land uses in the surrounding areas of the wetlands. Comparing the ordination and classification results of the plant communities, both methods displayed hydrologic gradients (water depth and hydro geomorphology), environmental factors (elevation and slope) and factors related to anthropogenic activities (drainage and disturbance) were important factors for plant species composition and vegetation assembly.

Results of canonical correspondence analyses and ANOVA test showed that six of the measured environmental factors (depth to the water, slope, drainage, disturbance, altitude and hydrogeomorphology) were significantly related to the floristic composition of the plant community types in Dabus and Fincha'a-Chomen wetlands. Results also showed that environmental factors such as water depth, slope, drainage and hydrogeomorphology were most significant factors that differentiated the floristic composition and distribution of the plant community types in Lake Abaya wetlands. In wetlands of Lake Chamo, only three of the measured variables (water depth, hydrogeomorphology and disturbance) had significant impact on the floristic composition and distribution of the plant community types. The most important environmental factors common to all sites were water depth and hydrogeomorphology. Water depth was the most important environmental factor which differentiated the plant community types from one another in all wetlands.

Plant communities which were found in relatively drier terrestrial landscape and in areas exposed for moderate disturbance (e.g. *Cynodon aethiopicus* from Lake Abaya and Chamo wetlands) were the most diverse and had the highest species richness and evenness values. In contrast to this, plant community types which occurred in deeper or standing water and experiencing prolonged inundation (e.g. *Cyperus articulatus*, *Typha angustifolia* and

Aeschynomene elaphroxylon from Lake Abaya and Chamo wetlands and *Cyperus papyrus* from Dabus marsh) were the least in species richness. Plant community types recorded from such areas were mainly dominated by few species. This is consistent with the proposal that permanent inundation may produce water zones dominated by stands of few species and a loss of terrestrial taxa (Brock, 1994). This also agrees with those of Grevilliot *et al.* (1998) who found that vegetation in frequently flooded and thus often waterlogged areas were characterised by high aerial biomass and low species diversity. The presence of standing water also affects the ability of some wetland plants to germinate leading to limited recruitment of new species in those zones and a subsequent reduction in species richness (Bornette *et al.*, 1998). Low species diversity of open water zones may be related to homogeneity of the aquatic habitats compared with the terrestrial ones. Moreover, the low diversity of the open water zone may be because most of its species are highly specific to that aquatic habitat, thus the same species occurs at nearly all sites. Research in different wetlands has indicated that prolonged inundation leads to low plant diversity (van der Valk *et al.*, 1994). Mitsch and Gosselink (1993) emphasized that water depth is frequently the most important environmental factor affecting plant species composition and distribution in wetlands.

Plant community types which were found in areas exposed for moderate disturbance had the highest diversity. Moderate disturbance of the existing vegetation by grazing animals and fishermen through cutting or burning of vegetation might also lead to increase in the species richness (Khedr and Doust, 2000). The relationship of community type one with high disturbance may explain its low diversity (Grime, 1973). Similar conclusions were made by Shaltout *et al.* (1994). Moderate disturbance often leads to distinct local variation in soil properties which meet the edaphic requirements of many species within communities (Khedr and Doust, 2000). Some species such as *Cynodon aethiopicus*, *Trifolium rueppellianum*, *Cyperus esculentus* and *Lindernia rotundata* were predominantly occurred in highly disturbed areas with less moisture gradient. Comparable distribution pattern to this was identified in Hurumu wetland in Illubabor Zone by Zerihun Woldu and Kumlachew Yeshitela (2003).

Community types which consisted of terrestrial species most commonly occurred in highly disturbed areas along low lying landscape with well drained or somewhat excessively drained soils and terrestrial landscape. It was associated with decreasing water level and moderate to steep slope gradient. Consistent with other studies (Howard, 1992; Starkey *et al.*, 2002) some forb and shrub species were associated with high altitude within the wetland system. A plausible explanation for this pattern is that most forbs and shrubs are less tolerant to inundation and therefore establish mainly at raised landforms.

Some community types and species from most community types occupied at around the origin of the CCA ordination diagram generated from the vegetation data from each study areas, showing that they prefer to grow in habitats of moderate values of all the parameters measured. Some plant community types were less distinctly recognized in the CCA ordination diagram due to the presence of species that may tolerate a wider range of habitat conditions. This further suggests that no single environmental factor but rather a combination of factors was significant in defining the variability within the species data.

The CCA ordination diagram displayed a measure of overlap among vegetation types and indicated various groups (plant community types) that uniquely occupy ordination space. One of the insights obtained from the ordination process was that the dominant graminoids (with several exceptions) were rather broadly distributed and overlapping in ordination space. Some of the meadow communities contained species more typical of shrub and marsh communities and some of the dominant plants in the shrub communities were species more due to increase in the number of cattle in the Lake Abaya and Chamo wetlands could contributed to the current spatial heterogeneity in species composition of weedy and invasive plant species. Most of the invasive and weedy plant species take advantage of the changes in site conditions, especially increase in nutrients following a significant disturbance (Milbau and Andi, 2004). Large herbivores influence species composition by removing herbage, trampling and through dung and urine depositions (Hobbs, 1991). Dung deposition modifies site conditions by supplying nutrients and facilitates seed dispersal (Hobbs, 1991). Rea and Storrs (1999) and DiTomaso (2000), reported that increase in cattle grazing effects such as trampling and nutrient inputs may accelerate the spread of invasive which consequently changes plant species composition and functional structure.

5.1.4. Rarefaction Analysis to Estimate Species Richness

The Coleman (2005) rarefaction species richness estimator curves for the vegetation types showed a similar trend as the Simpson and Shannon-Wiener indices with the same vegetation types having high estimates of species richness (Figure 5.7). The Dabus vegetation type had the highest non-asymptotic species accumulation curve than all the sites (Figure 5.7). Therefore, it had the most species richness. If we had only collected from 78 plots at Dabus, we would expect to record 118 species (comparing all curves at the point on the x-axis corresponding to the site with lowest sampling intensity, Lake Chamo with 78 samples). So Dabus marsh really was richer than any other site. The other three study sites (Fincha-Chomen, Abaya and Chamo) had asymptotic curves with less species richness. Fincha Chomen had lowest species accumulation curve than all the sites. Therefore, it had the least species richness. Wetlands of Lake Chamo (shallow lake) had higher species accumulation curve than the wetlands of Lake Abaya (deeper lake). But it had the fewest number of plots of all sites. This is in agreement with those of Schulthorpe (1967) who considers that shallow lakes support significantly more species number. The different morphology of the basin of the Abaya Lake, which is deep and not favourable for emergent plants over a large proportion of its shoreline, might be a reason for the lower species number expected in the releves of this lake.

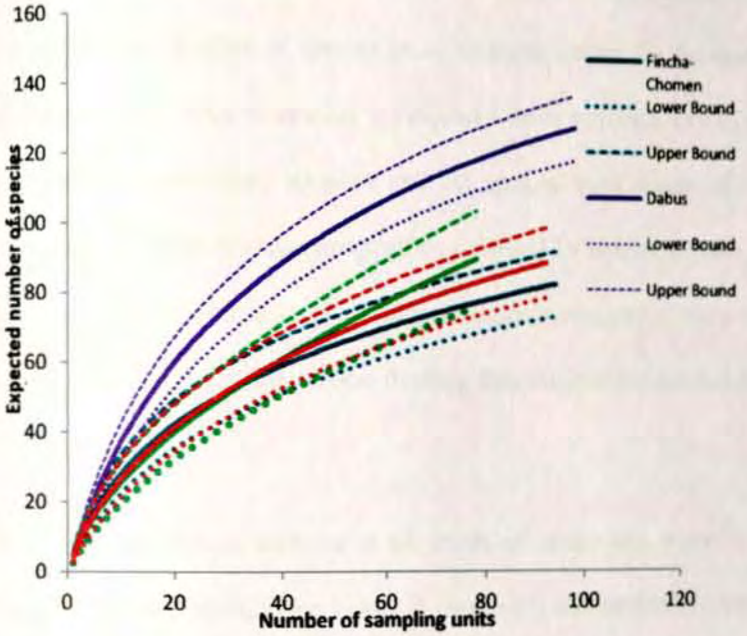


Figure 5.7: Sample based rarefaction curves of study sites with 95% confidence intervals (y-xis indicates an expected number of species and x-axis corresponds to the sampling intensity of the sites or number of sampling units)

5.2. Conclusion and Recommendations

The study has resulted in the documentation of 303 plant species representing 194 genera and 72 families. Eleven families, fifteen genera and six species were found to be common to all wetlands. Families which had the highest contribution to the overall species composition of the wetlands were Poaceae, Asteraceae, Fabaceae, and Cyperaceae. Poaceae was the family with the highest number of species in all wetlands except for the family Cyperaceae which had the highest number of species in Fincha-Chomen wetlands. Out of the total species, seven were endemic, two were invasive and six species were weeds of cultivated land. Herbs occupied the highest floristic composition followed by sedges, grasses and shrubs at all study sites. Most of the plants in the wetlands under investigation were emergent macrophytes except a few of them that were free-floating, floating-leaf and submerged species.

Dabus was the richest wetland at all levels of taxonomic diversity. Wetlands of similar elevations (Abaya and Chamo Lakes in particular) and environmental conditions were more similar in floristic composition. Wetlands had similar number of plant community types but the species turnovers between communities were rather high for all sites. Wetlands of Lake Abaya had relatively the highest number of plant community types during both wet and dry seasons. Equal numbers of community types were recorded from the remaining study sites during both survey periods. Different plant community types were identified from the wetlands.

The highest number of wetland associated and wetland dependent species were recorded from Dabus and Fincha-Chomen wetlands. In addition to its highest diversity at all taxonomic levels, Dabus was also an important reservoir of relatively the highest number of endemic plants. Hence, Dubus could serve the purpose of biodiversity conservation. On the other hand, an invasive and weedy but not endemic species were recorded from wetlands of the two lakes. Moreover, a plant community type dominated by an invasive species was recorded from wetlands of the two lakes during both survey periods. Thus, the presence of weedy, introduced or invasive species and plant community types dominated by these species might indicate a relatively more anthropogenic disturbance effect of land use on wetlands of Lake Abaya and Chamo.

The distribution and composition of plant species and vegetation assembly at each study site were influenced significantly by a combination of different environmental factors. At each wetland, the dominant grasses and sedges were widely distributed resulting in an overlap among plant community types. Furthermore, the study on the wetlands resulted in plant communities of mainly emergent species, aggregating free floating, floating-leaf and submerged plants as minor members of associations dominated by the more obvious emergent species and did not indicate the differences that may exist between emergent and submerged plants as distinct components of wetland communities. Thus, the presence of non-wetland shrub and forb species and their high frequency in the wetlands indicated that all the wetlands were experiencing disturbances from both natural environment and anthropogenic factors.

Results of the study showed that there were differences between and among the wetlands in the spatial and temporal patterns of plant species composition and diversity due to variations in environmental gradients (hydrologic factors in particular) and anthropogenic factors. Therefore, this should be considered in future management and protection under the circumstance of climate change and human activities. Overall, results support the prediction that different environmental variables had varying influence on the overall plant species composition, diversity and distribution.

Long term monitoring of the wetland plant communities is recommended as the environment changes with increased human activities that are likely to increase the abundance of invasive species. The number and cattle movements should be controlled in order to maintain the integrity of the wetlands. Further study of soil nutrients and water chemistry data is recommended to better understand the compositional variation found between and among the wetlands. In addition, an assessment of the vegetation in terms of its variability and reaction to various practices such as burning and grazing should be done.

Protective measures should be developed to safeguard the study areas from destructive anthropogenic impacts; otherwise the damage can become irreversible. The effective and continuous protection measures should be identified and local community should be informed about the importance of the conservation of these fragile ecosystems. Wetland managers and decisions makers at all levels should consider this baseline data on the species composition and vegetation ecology to guide management decisions and to detect changes over time and space as a result of management and impacts of anthropogenic alteration. They should also make use of the relationships between environmental factors and wetland plant communities and the subsequent interpretation as a valuable tool in the planning of future development, conservation and management of the wetland vegetation.

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APPENDICES

Appendix 1a: List of species with their families recorded from Lake Abaya
(* = endemic, **= invasive, *** = weeds)

No.	Name of species with authority name(s)	Family	Local name	Coll. No.
1	*Acacia montigena* Brenan & Exell	Fabaceae		AT4P2
2	*Acacia seyal* Del.	Fabaceae	Odooruwaa	AT5P3
3	*Acacia tortilis* (Forssk.) Hayne	Fabaceae		AT1P31
4	*Acalypha fruitcosa* Forssk.	Euphorbiaceae	Dijileh	AT1P32
5	*Acalypha racemosa* Baill.	Euphorbiaceae	Kusamol	AT4P3
6	*Achyranthes aspera* L.	Amaranthaceae		AT1P22
7	*Aeschynomene elaphroxylon* (Guill. & Perr.) Taub.	Fabaceae	Sokkee	AT1P3
8	*Ajuga alba* (Guerke) Robyns	Lamiaceae		AT6P1
9	*Aloe otallensis* Baker	Aloacece		AT2P3
10	*Amaranthus dubius* Thell.	Amaranthaceae		AT7P21
11	****Amaranthus hybridus* L.	Amaranthaceae	Gagabisaa	AT7P22
12	****Amaranthus spinosus* L.	Amaranthaceae		AT8P3
13	*Balanites aegyptiaca* Del.	Balanitaceae	Badanna	AT8P4
14	*Buchnera hispida* Benth.	Scrophulariaceae		AT8P5
15	*Carissa spinarum* L.	Apocynaceae	Ladiyaa	AT8P6
16	*Cayratia ibuensis* (Hook.f.) Suesseng	Vitaceae	Menenako	AT10P3
17	*Cissus quadrangularis* L.	Vitaceae		AT10P4
18	*Clausena anisata* (Willd.) Benth.	Rutaceae	Kataariyaa	AT10P5
19	*Commelina diffusa* Burm.f.	Commelinaceae	Dalishaa	AT10P6
20	*Cordia africana* Lam.	Boraginaceae	Moqotta	AT10P7
21	*Croton macrostachyus* Del.	Euphorbiaceae	Ankaa	AT10P8
22	*Cynodon aethiopicus* Clayton & Harlan	Poaceae	Gorxaa	AT3P1
23	*Cyperus alopecuroides* Rottb.	Cyperaceae	Dilla	AT4P4
24	*Cyperus articulatus* L.	Cyperaceae	Katemaa	A18T1P1
25	*Cyperus dichroostachyus* A. Rich.	Cyperaceae		A18T1P2
26	*Cyperus digitatus* Steud.	Cyperaceae		A18T1P3
27	*Cyperus distans* L.f.	Cyperaceae		A18T1P4
28	*Cyperus grandibulbosus* C. B. Clarke	Cyperaceae		AT3P03
29	*Cyperus laevigatus* L.	Cyperaceae		AT6P2
30	*Cyperus latifolius* Poir.	Cyperaceae		AT1P02
31	*Cyperus papyrus* L.	Cyperaceae		AT9P1
32	*Cyperus pectinatus* Vahl	Cyperaceae		AT11P2
33	*Cyperus rotundus* L.	Cyperaceae		AT8P5
34	*Cyperus subumbellatus* Kuk.	Cyperaceae		AT4P1
35	****Datura stramonium* L.	Solanaceae	Macharaa	AT14P2
36	****Echinochloa colona* (L.) Link	Poaceae	Sharafaa	AT14P3
37	*Echinochloa haploclada* (Stapf) Stapf	Poaceae		AT14P4
38	*Echinochloa pyramidalis* (Lam.) Hitchc. & Chase	Poaceae	Kordodo	AT16P1
39	*Eclipta prostrata* L.	Asteraceae		AT16P2

40	***Eichhornia crassipes* (Mart.) Solms in A. DC.	Pontederaceae		AT16P3
41	*Enneapogon desvauxii* P. Beauv.	Poaceae		AT16P4
42	*Eragrostis japonica* (Thunb.) Trin.	Poaceae		AT16P5
43	*Eriochloa fatmensis* (Hochst. & Steud.) Clayton	Poaceae		AT16P6
44	*Euphorbia tirucalli* L.	Euphorbiaceae	Matsuwaa	AT13P3
45	*Ficus ovata* Vahl	Moraceae	Boba	AT13P4
46	*Ficus sur* Forssk.	Moraceae	Maruwaa	AT13P5
47	*Ficus sycomorus* L.	Moraceae	Sholaa	AT13P6
48	*Geigeria alata* (DC.) Benth. & Hook.	Asteraceae	Dorsa qarchochuwa	AT1P3
49	*Gossypium barbadense* L.	Malvaceae	Futtuwaa	AT2P5
50	*Grewia ferruginea* Hochst. ex A. Rich.	Tiliaceae		AT2P1
51	*Grewia villosa* Sch. Bip.	Tiliaceae	Lohaa, ogadie	AT11P3
52	*Guizotia scabra* (vis) Chiov.	Asteraceae		AT11P4
53	*Hippocratea africana* (Willd.) Loes.	Celastraceae		AT11P5
54	*Hypoestes forskaolii* (Vahl) R. Br.	Acanthaceae		AT11P6
55	*Ipomoea aquatica* Forssk.	Convolvulaceae	Chonyaa	AT10P2
56	*Ipomoea eriocarpa* R. Br.	Convolvulaceae		AT15P1
57	*Kigelia africana* (Lam.) Benth.	Bignoniaceae		AT15P3
58	*Leersia hexandra* Sw.	Poaceae	Aregash mata	AT5p5
59	*Leptadenia arborea* (Forssk.) Decne	Asclepiadaceae	Harare mafakiya	AT1P01
60	*Leptochloa fusca* (L.) Kunth	Poaceae		AT7P3
61	*Leucas deflexa* Hook. f.	Lamiaceae		AT6P3
62	*Ludwigia stolonifera* (Guill & Perr.) P.H. Raven	Onagrnaceae		AT12P02
63	*Lycopersicun esculentum* Mill.	Solanaceae		AT7P1
64	*Mangifera indica* L.	Anacardiaceae	Manguwaa	AT7P2
65	*Maytenus arbutifolia* (A. Rich.) Wilczek	Celastraceae	Ome	AT7P4
66	*Maytenus senegalensis* (Lam.) Exell	Celastraceae	Tutuwa	AT1P3
67	*Melhania ovata* (Cav.) Spreng.	Sterculiaceae	Lolaa	AT1P3
68	*Nymphaea nouchali* Burm. F.	Nymphaeaceae	Dupa	AT2P4
69	*Nymphaea lotus* L.	Nymphaeaceae	Dupa	AT1P5
70	*Panicum repens* L.	Poaceae	Lasuwaa	AT3P0
71	*Panicum trichocladum* K. Schum.	Poaceae		AT3P26
72	*Phalaris arundinacea* L.	Poaceae	Shimel, Ketsem	AT6P11
73	*Phragmites karka* (Retz.) Steud.	Poaceae	Litsabad	AT1P4
74	*Pistia stratiotes* L.	Araceae		AT2P13
75	*Plecthrantus barbatus* Andrews	Lamiaceae	Sah	AT11P03
76	*Pluchea ovalis* (Pers.) DC.	Asteraceae	Buzuwa	AT2P7
77	*Potamogeton pucillus* L.	Potamogetonaceae		AT2P5
78	*Pulicaria schimperi* DC.	Asteraceae		AT1P4
79	*Senna didymobotrya* (Fresen.) Irwin & Barneby	Fabaceae	Tosho	AT1P4

80	*Senna septemtrionalis* (Viv.) Irwin & Barneby	Fabaceae	Bitsendo	AT1P5
81	*Sesbania sesban* (L.) Merr.	Fabaceae	Sharshanto	AT2P1
83	*Schoenoplectus confusus* (N. E. Br.) Lye	Cyperaceae	Chooccaa	AT1P21
84	*Solanum incanum* L.	Solanaceae	Buluwaa	AT1P23
85	*Sorghum verticilliflorum* (Steud.) Stapf	Poaceae	Ficho	AT2P1
86	*Spathodea nilotica* Seem.	Bignoniaceae		AT6P5
87	*Spirodela polyrrhiza* (L.) Schleiden	Lemnaceae		AT5P6
88	*Trichilia emetica* Vahl.	Meliaceae	Dimo	AT2P8
89	*Typha angustifolia* L.	Typhaceae	Alaa (Filaa)	AT1p2
90	*Withania somnifera* (L.) Dunal.	Solanaceae		AT6P4
91	*Wolffia arrhiza* (L.) Horkel ex Wimmer	Lemnaceae		AT3P5
92	****Xanthium strumarium* L.	Asteraceae	Cagagotiyaa	AT3P3

Appendix 1b: List of species with their families recorded from Lake Chamo
(* = endemic, **= invasive, *** = weeds)

No.	Name of species with authority name(s)	Family	Local name	Coll. No.
1	*Abutilon fruticosum* Guill. & Perr.	Malvaceae		CT14P37
2	*Acacia abyssinica* Hochst. ex Benth.	Fabaceae		CT14P38
3	*Acacia seyal* Del.	Fabaceae	Odooruwaa	CT1P23
4	*Acacia tortilis* (Forssk.) Hayne	Fabaceae		CT11P35
5	*Acalypha racemosa* Baill.	Euphorbiaceae	Dandreta	CT6P36
6	*Achyranthes aspera* L.	Amaranthaceae		CT12P9
7	*Acmella caulirhiza* Del.	Asteraceae		CT12P10
8	*Aeschynomene elaphroxylon* (Guill. & Perr.] Taub	Fabaceae	Sokkee	CT12P11
9	*Ageratum conyzoides* L.	Asteraceae	Marimato	CT8P55
10	*Albizia malacophylla* (A. Rich.) Walp.	Fabaceae		CT3P18
11	****Amaranthus hybridus* L.	Amaranthaceae	Gagabisaa	CT8P42
12	****Amaranthus spinosus* L.	Amaranthaceae		CT8P53
13	*Balanites aegyptiaca* Del.	Balanitaceae		CT8P54
14	*Bidens pilosa* L.	Asteraceae		CT8P55
15	*Brachiaria brizantha* (A. Rich.) Stapf	Poaceae	Gorxaa	CT8P56
16	*Calpurnia aurea* (Ait.) Benth.	Fabaceae	Koshiyaa	CT8P57
17	*Cayratia ibuensis* (Hook.f.) Suesseng	Vitaceae		CT1P27
18	*Cleome gynandra* L.	Capparidaceae	Keto	CT8P44
19	*Conyza agrostophylla* F. G. Davies	Asteraceae		CT1P10
20	*Talinum portulacifolium* (Forssk.) Aschers. ex Schweinf.	Portulacaceae e		CT1P11
21	*Cynodon aethiopicus* Clayton & Harlan	Poaceae	suraa	CT1P12
22	*Cyperus articulatus* L.	Cyperaceae		CT1P11
23	*Cyperus conglomerates* Rottb.	Cyperaceae		CT8P32
24	*Cyperus imbricatus* Retz.	Cyperaceae		CT13P15
25	*Cyperus latifolius* Poir.	Cyperaceae		CT9P25
26	*Cyperus welwitschii* (Ridl.)Lye	Cyperaceae		CT9P26

27	*Dinebra retroflexa* (Vahl) Panzer	Poaceae		CT14P36
28	****Echinochloa colona* (L.) Link	Poaceae	Sharafaa	CT3P11
29	*Echinochloa pyramidalis* (Lam.) Hitchc. & Chase	Poaceae	Kordodo	CT3P12
30	*Eclipta prostrata* (L.) L.	Asteraceae		CT8P45
31	***Eichhornia crassipes* (Mart.) Solms in A. DC.	Pontederaceae		CT2P43
32	*Eleusine floccifolia* (Forssk.) Spreng.	Poaceae		CT18P21
33	*Eleusine indica* (L.) Gaertn.	Poaceae	Gorttaa	CT18P22
34	*Enydra fluctuans* Lour.	Asteraceae		CT12P24
35	*Eragrostis cilianensis* (All.) Vign. Ex Janchen	Poaceae		CT12P25
36	*Ficus sycomorus* L.	Moraceae	Sholaa	CT12P26
37	*Geigeria alata* (DC.) Benth. & Hook.	Asteraceae	Dorsa qarchochuwa	CT1P13
38	*Gomphocarpus semilunatus* A. Rich.	Asclepiadaceae		CT2P12
39	*Guizotia scabra* (vis) Chiov.	Asteraceae		CT2P13
40	*Hibiscus cannabinus* L.	Malvaceae		CT14P35
41	*Hibiscus crassinervius* Hochst. ex A. Rich.	Malvaceae		CT5P24
42	*Hibiscus micranthus* Hochst. ex A. Rich.	Malvaceae		CT5P25
43	*Hibiscus vitifolius* L.	Malvaceae	Fudo	CT6P35
44	*Hydrocotyle ranunculoides* L.f.	Apiaceae		CT17P21
45	*Pennisetum polystachion* (L.) Schult.	Poaceae	Duppaa	CT17P22
46	*Perotis patens* Gand.	Poaceae		CT17P23
47	*Phalaris arundinacea* L.	Poaceae		CT14P34
48	*Phragmites karka* (Retz.) Steud.	Poaceae	Litsabad	CT2P44
49	*Plecthrantus punctatus* (L.f.) L'Her	Lamiaceae	Sah	CT17P24
50	*Pluchea dioscoidis* (L.) DC.	Asteraceae		CT2P53
51	*Pluchea ovalis* (Pers.) DC.	Asteraceae	Buzuwa	CT1P22
52	*Potamogeton pucillus* L.	Potamogetonaceae		CT1P28
53	*Ricinus communis* L.	Euphorbiaceae	Kobbuwaa	CT2P12
54	*Rubus steudneri* Schweinf.	Rubiaceae	Xuxuwaa	CT17P11
55	*Satureja abyssinca* (Benth.) Briq.	Lamiaceae	Injemaa	CT17P12
56	*Senna didymobotrya* (Fresen.) Irwin & Barneby	Fabaceae		CT13P12
57	*Senna septemtrionalis* (Viv.) Irwin& Barneby	Fabaceae	Tosho	CT17P13
58	*Sesbania goetzei* Harms	Fabaceae	Bitsendo	CT9P13
59	*Sesbania sesban* (L.) Merr.	Fabaceae	Sharshanto	CT8P13
60	*Solanum incanum* L.	Solanaceae	Buluwaa	CT17P17
61	*Sphaeranthus suaveolens* (Forssk.) DC.	Asteraceae		CT2P32
62	*Spilanthes costata* Benth.	Asteraceae	Garbule	CT2P33
63	*Commelina diffusa* Burm.f.	Commelinacea		CT15P10
64	*Thelypteris confluens* Schott.	Thelypteridaceae		CT15P11
65	*Tribulus terrestris* L.	Zygophyllaceae		CT15P12
66	*Typha angustifolia* L.	Typhaceae	Filaa	CT14P33

67	*Vernonia abyssinica* Fresen.	Asteraceae		CT1P24
68	*Vigna heterophylla* A. Rich.	Fabaceae		CT2P55
69	****Xanthium strumarium* L.	Asteraceae		CT6P13
70	*Indigofera atriceps* Hook.f.	Fabaceae	Cagagotiyaa	CT13P16
71	*Indigofera trita* L.f.	Fabaceae		CT15P14
72	*Ipomoea aquatica* Forssk.	Convolvulaceae		CT8P59
73	*Ipomoea eriocarpa* R. Br.	Convolvulaceae		CT13P14
74	*Hypoestes triflora* (Forssk.) Roem & Schult.	Acanthaceae		CT8P43
75	*Kedrostis hirtella* (Naud.) Cong.	Cucurbitaceae		CT1P21
77	***Lantana camara* L.	Verbenaceae		CT2P33
78	*Leersia hexandra* Sw.	Poaceae	Aregash mataa	CT1P26
79	*Leptadenia hastata* (Forssk.) Decne	Asclepiadaceae		CT16P312
80	*Leptochloa fusca* (L.) Kunth	Poaceae		CT8P54
81	*Loudetia phragmatoides* (Peter) C.E. Hubb.	Poaceae		CT1P25
82	*Ludwigia stolonifera* (Guill & Perr.) P.H. R aven	Onagrnaceae		CT14P32
83	*Maytenus senegalensis* (Lam.) Exell	Celastraceae	Tutuwa	CT9P28
84	*Mikania capensis* DC.	Asteraceae		CT16P31
85	*Nymphaea nouchali* Burm. F.	Nymphaeaceae	Dupa	CT2P41
86	*Nymphaea lotus* L.	Nymphaeaceae	Dupa	CT6P33
87	*Panicum maximum* Jacq.	Poaceae		CT14P31
88	*Paspalidium geminatum* (Forssk.) Stapf	Poaceae		CT13P11

Appendix 1c: List of species with their families recorded from Fincha'a-Chomen Marsh (* = endemic, **= invasive, *** = weeds)

No.	Name of species with authority name(s)	Family	Local name	Coll. No.
1	*Acacia seyal* Del.	Fabaceae	Wachu	FC58
2	*Achyranthes aspera* L.	Amaranthaceae	Darguu	FC7
3	*Aeschynomene schimperi* Hochst. ex A.Rich.	Fabaceae	Ena dima	FC72
4	*Ajuga leucanthus* (Guerke) Robyns	Lamiaceae	Ambachii	FC74
5	****Amaranthus spinosus* L.	Amaranthaceae		FC80
6	*Ascolepis capensis* (Kunth) Ridl.	Cyperaceae		FC127
7	*Brachiaria brizantha* (A. Rich.) Stapf	Poaceae		FC5
8	*Brachiaria pubescence* (Chiov.) S.M. Phillips	Poaceae		FC94
9	*Carissa spinarum* L.	Apocynaceae	Agamsa	FC62
10	*Chenopodiuim album* L.	Chenopodiaceae		FC70
11	*Chenopodiuim schroderianum* Schult.	Chenopodiaceae	Adala	FC15
12	*Clausena anisata* (Willd.) Benth.	Fabaceae	Ulumayi	FC86
13	*Commelina diffusa* Burm.f.	Commelinaceae	Qarxobii	FC16
14	*Cordia africana* Lam.	Boraginaceae	Waddessaa	FC46
15	*Croton macrostachyus* Del.	Euphorbiaceae	Bakkanniisa	FC51

16	*Cynodon aethiopicus* Clayton & Harlan	Poaceae	Coqorsa	FC1
17	*Cyperus assimilis* Steud.	Cyperaceae		FC97
18	*Cyperus atroviridis* C.B. Clarke	Cyperaceae		FC67
19	*Cyperus denudatus* L.f.	Cyperaceae		FC151
20	*Cyperus dichroostachyus* A. Rich.	Cyperaceae	Caafee	FC20
21	*Cyperus digitatus* Roxb.	Cyperaceae	Caffee	FC37
22	*Cyperus elegantulus* Steud.	Cyperaceae	Quunnii	FC28
23	****Cyperus esculentus* L.	Cyperaceae	Quunnii	FC11
24	*Cyperus grandibulbosus* C.B. Clarke	Cyperaceae		FC64
25	*Cyperus latifolius* Poir.	Cyperaceae	Cheffe mana	FC77
26	*Cyperus longibracteatus* (Cherm.) Kuk.	Cyperaceae	Daaggoo	FC87
27	*Cyperus munditii* (Nees) Kunth	Cyperaceae		FC25
28	*Cyperus nitidus* Lam.	Cyperaceae	Qunni	FC79
29	*Cyperus pectinatus* Vahl	Cyperaceae	Qunni	FC42
30	*Cyperus rotundus* L.	Cyperaceae	Qeexamaa	FC81
31	*Cyperus rubicundus* Vahl	Cyperaceae		FC89
32	*Cyperus welwitschii* (Ridl.)Lye	Cyperaceae		FC66
33	****Datura stramonium* L.	Solanaceae	Asenagrii	FC83
34	*Echinochloa stagnina* (Retz.) P. Beauv.	Poaceae		FC60
35	*Echinops hispidus* Fresen.	Asteraceae	Qoree Harree	FC6
36	*Eleusine floccifolia* (Forssk.) Spreng.	Poaceae	Barankiya	FC65
37	*Eragrostis tenuifolia* (A. Rich.) Steud.	Poaceae	Ashufe	FC2
38	*Eriocaulon Schimperi* Kom. ex.Ruhland	Eriocaulaceae		FC38
39	*Eriochloa fatmensis* (Hochst. & Steud.) Clayton	Poaceae		FC59
40	*Eriochrysis pallida* Munro	Poaceae		FC50
41	*Eucalyptus botryoides* Smith	Myrtaceae	Akakilti	FC52
42	*Fimbristylis complanata* (Retz.) Link	Cyperaceae	Quunnii	FC43
43	*Fimbristylis ferruginea* (L.) Vahl	Cyperaceae		FC40
44	*Floscopa glomerata* (Willd. ex J.A. Schult. & J.H. Schult.) Hassk.	Cyperaceae	Lima	FC54
45	*Fuirena stricta* Steud.	Cyperaceae		FC73
46	*Lindernia rotundata* (Pilg.) Eb. Fisch	Scrophulariaceae		FC10
47	*Liphocarpha constricta* Goetgh.	Cyperaceae		FC109
48	*Ludwigia stolonifera* (Guill. & Perr.) P. H. Raven	Onagraceae	Muko cheffe	FC36
49	*Measa lanceolata* Forssk.	Myrsinaceae	Abbayyii	FC56
50	*Mentha aquatica* L.	Lamiaceae		FC110
51	*Nymphaea nouchali* Burm. F.	Nymphaeceae		FC88
53	*Panicum hygrocharis* Steud.	Poaceae	Marga-gorgorri	FC23
54	*Pennisetum glabrum* Pilg.	Poaceae	Migira	FC82
56	*Pennisetum thunbergii* Kunth.	Poaceae		FC4
57	*Persicaria deciepens* (R. Br.) K. L. Wilson	Polygonaceae		FC31

58	*Phagnalon phagnaloides* (Hochst. ex A. Rich.) Cufod.	Asteraceae		FC57
59	****Plantago lanceolata* L.	Plantaginaceae	Qorxobi	FC14
60	*Plectranthus punctatus* (L.f.) L'Her.	Lamiaceae	Siqaaqimee	FC9
61	*Podocarpus falcatus* Thumb.) R.B. ex Mirb.	Podocarpaceae	Birbirsa	FC13
62	*Polygonum amphibium* L.	Polygonaceae	Dengego cheffe	FC21
63	*Polygonum senegalense* Meisn.	Polygonaceae	Yeho	FC69
64	*Ranunculus multifidus* Forssk.	Ranunculaceae	Araba	FC32
65	*Rubus stuedneri* Schweinf.	Rubiaceae	Gora	FC44
66	**Satureja paradoxa* (Vatke) Engl. ex Seybold	Lamiaceae	Kefoo sa'aa	FC41
67	**Satyrium aethiopicum* Summerh	Orchidaceae		FC90
68	**Scadoxus nutans* (Friis & Bjørnstad) Friis & Nordal	Amaryllidaceae		FC63
69	*Sesbania sesban* (L.) Merr.	Fabaceae	Harchaa	FC26
70	*Schoenoplectus confusus* (N.E. Br.) Lye	Cyperaceae		FC24
71	*Schoenoplectus corymbosus* (Roem. & Schult.) Rayn.	Cyperaceae	Qalandu	FC49
72	*Solanum incanum* L.	Solanaceae	Hiddii loonii	FC17
73	*Sphaeranthus suaveolens* (Forssk.) DC.	Asteraceae	Gabisa	FC71
74	*Spilanthes costata* Benth.	Asteraceae	Gororsa	FC53
75	*Swertia usambarensis* Engl.	Gentianaceae		FC19
76	*Syzygium guineense* subsp. *macrocarpum* (Engl.) F. White	Myrtaceae	baddeessaa	FC61
77	*Thelypteris confluens Schott.*	Thelypteridaceae	Geto chefe	FC33
78	*Trifolium rueppellianum* Fresen.	Fabaceae		FC3
79	*Typha latifolia* L.	Typhaceae	Fila	FC84
80	*Vernonia abyssinica* Fresen.	Asteraceae	Soyamaa	FC35
81	*Xyris capensis* Thumb.	Xyridaceae		FC29
82	*Gomphocarpus semilunatus* A. Rich.	Asclepediaceae		FC55
83	*Guizotia abyssinica* (L.f.) Cass.	Asteraceae	Nuugii	FC8

84	*Guizotia scabra* (Vis) Chiov.	Asteraceae	Hada	FC12
85	*Hydrocotyle mannii* Hook.f.	Apiaceae	Cenna	FC22
86	*Hydrocotyle ranunculoides* L.f.	Apiaceae	Nobe	FC34
87	*Hypericum pepidifolium* Oliv.	Hypericaceae		FC30
88	*Hypoxis vilosa* L.f.	Hypoxidaceae		FC78
89	*Impatiens aethiopica* Grey-Wilson	Balsaminaceae	Maga cheffe	FC85
90	*Juncus oxycarpus* E. Meyer ex Kunth	Juncaceae		FC39
91	*Kyllinga odorata* Vahl	Cyperaceae		FC18
92	*Kyllingiella polyphylla* (A. Rich.) Lye	Cyperaceae		FC27

Appendix 1d: List of species with their families recorded from Dabus Marsh
(* = endemic, **= invasive, *** = weeds)

No.	Name of species with authority name(s)	Family	Local name	Coll. No.
1	*Acacia abyssinica* Hochst. ex Benth	Fabaceae	Laafto	D137
2	*Acacia montigena* Brenan& Exell	Fabaceae	Laafto	D115
3	*Achyranthes aspera* L.	Amaranthaceae	Samaxxee	D8
4	*Achyrospermum schimperi* (Hochst. ex Briq.) Perkins	Lamiaceae	Kussayyee	D149
5	*Aeschynomene schimperi* Hochst. ex A. Rich.	Fabaceae	Ena dima	D72
6	*Ajuga leucanthus* (Guerke) Robyns	Lamiaceae	Ambachl	D74
7	*Albizia malacophylla* (A. Rich.) Walp.	Fabaceae	Arganboobee	D130
8	*Albizia schimperiana* Oliv.	Fabaceae	Mukaarba	D99
9	**Ascolepis eriocauloides* (Steud.) Steud.	Cyperaceae		D132
10	*Bidens pilosa* L.	Asteraceae	Uffo	D91
11	*Bidens ternata* (Chiov.) Sherff	Asteraceae		D135
12	*Brachiaria brizantha* (A. Rich.) Stapf	Poaceae		D5
13	*Brachiaria pubescence* (Chiov.) S. M. Phillips	Poaceae		D111
14	*Buchnera capitata* Benth.	Scrophulariaceae		D128
15	*Carex bequaertii* De Wild.	Cyperaceae		D96
16	*Carex monostachya* A. Rich.	Cyperaceae		D165
17	*Chenopodiuim schroderianum* Schult.	Chenopodiaceae	Qoricha	D15
18	*Coffea arabica* L.	Rubiaceae	Buna	D133
19	*Comberatum collinum* Fresen.	Comberetaceae	Gomorii	D104
20	*Commelina diffusa* Burn.f.	Commelinaceae	qarxobii	D16
21	*Cordia africana* Lam.	Boraginaceae	Waddessaa	D46
22	*Costus afer* Ker-Gawl	Costaceae		D122

23	*Crassocephalum rubens* (Juss. ex Jacq.) S. Moore	Asteraceae		D131
24	*Croton macrostachyus* Del.	Euphorbiaceae	Bakkanniisa	D51
25	*Cynodon aethiopicus* Clayton & Harlan	Poaceae	Coqorsa	D1
26	*Cyperus atroviridis* C. B. Clarke	Cyperaceae		D153
27	*Cyperus dichroostachyus* A. Rich.	Cyperaceae	Caafee	D20
28	*Cyperus digitatus* Roxb.	Cyperaceae	Ashuufee	D37
29	*Cyperus distans* L.f.	Cyperaceae	Qunnii/Daggoo	D124
30	*Cyperus dives* Del.	Cyperaceae	Daaggoo	D6
31	*Cyperus fischerianus* A. Rich.	Cyperaceae	Dhalladuu	D142
32	*Cyperus flavescens* L.	Cyperaceae	Cheffe mana	D141
33	*Cyperus latifolius* Poir.	Cyperaceae		D77
34	*Cyperus papyrus* L.	Cyperaceae	Yebeloo	D102
35	*Cyperus rigidifolius* Steud.	Cyperaceae	Quunnii	D140
36	*Cyperus triceps* Endl.	Cyperaceae		D151
37	*Cyperus uniolodes* R. Br.	Cyperaceae		D172
38	*Digitaria ciliaris* (Retz.) Koel.	Poaceae		D93
39	*Dioscorea bulbifera* L.	Dioscreaceae	Kooteharree	D179
40	*Dracaena steudneri* Engl.	Dracenaeae	Lankuso	D139
41	*Echinochloa rotundiflora* Clayton	Poaceae		D116
42	*Echinochloa stagnina* (Retz.) P. Beauv	Poaceae		D60
43	*Echinops amplexicaulis* Oliv.	Asteraceae		D169
44	*Echinops hispidus* Fresen.	Asteraceae	Qoree Harree	D7
45	*Eleocharis acutangula* (Roxb.) Schult.	Cyperaceae		D95
46	*Eleusine coracana* (L.) Gaertn.	Poaceae	Dagujjaa	D92
47	*Eragrostis botryodes* W.D. Clayton	Poaceae		D186
48	*Eriochloa fatmensis* (Hochst. & Steud.) Clayton	Poaceae		D59
49	*Echinochloa pyramidalis* (Lam.) Hitchc. & Chase	Poaceae		D144
50	**Erythrina brucei* Schweinf.	Fabaceae	Waleensu	D113
51	*Euclea divinorum* Hiern	Ebenaceae	M'eessaa	D152
52	*Ficus sur* Forssk.	Moraceae	Arbu	D161
53	*Ficus sychomorus* L.	Moracaeae	Odaa	D98
54	*Ficus vasta* Forssk.	Moraceaea	Qilxu	D114
55	*Floscopa glomerata* (Willd. ex J. A. Schult. & J.H. Schult.) Hassk.	Cyperaceae		D54
56	*Galiniera coffeoides* Del.	Rubiaceae	Adamo	D160
57	*Galinsoga quadriradiata* Ruiz. and Pavon	Asteraceae	Aramaa	D109
58	*Grewia mollis* Juss.	Tiliacaea	Aroresa, uffo	D107
59	*Guizotia abyssinica* (L. f) Cass.	Asteraceae	Nuugii	D9
60	*Guizotia scabra* (Vis) Chiov.	Asteraceae	Tuufoo	D178
61	*Habenaria zambesiana* Rchb.f.	Orchidaceae		D173
62	*Hyparrhenia hirta* (L.) Stapf	Poaceae	Delan, Citaa	D177
63	*Hyparrhenia rufa* (Nees) Stapf	Poaceae	Daggala	D176

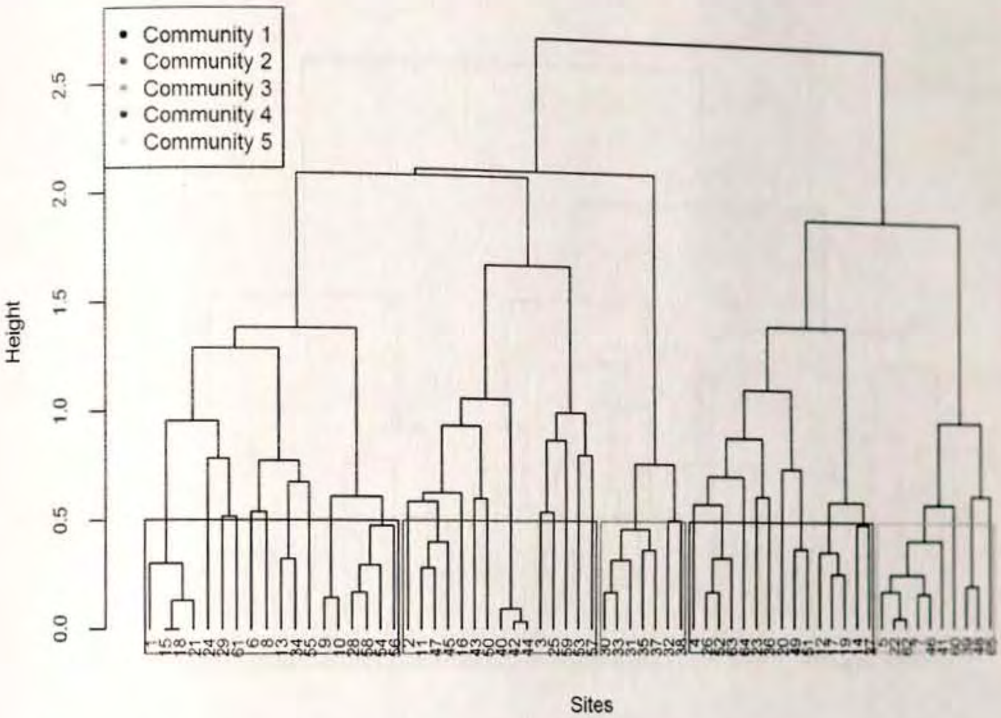
64	*Impatiens aethiopica* Grey-Wilson	Balsaminaceae	Maga cheffe	D85
65	*Keetia zanzibarica* (Klotzsch) Bridson	Rubiaceae		D120
66	*Kohautia coccinea* Royle	Rubiaceae		D180
67	*Kotschya africana* Endl.	Fabaceae	Heenna	D129
68	*Lannea fruitcosa* (Hochst ex A. Rich) Engl.	Anacardiaceae		D105
69	*Leersia hexandra* Sw.	Poaceae	Kemete	D23
70	*Leucas deflexa* Hook.f.	Lamiaceae		D125
71	*Liphocarpha chinensis* (Osb.) Kern	Cyperaceae		D162
72	*Loudetia arundinacea* (Hochst. ex A. Rich.) Steud.	Poaceae		D143
73	*Ludwigia abyssinica* A. Rich.	Onagraceae	Muko cheffe	D73
74	*Measa lanceolata* Forssk.	Myrsinaceae	Abbayyii	S56
75	**Millettia ferruginea* (Hochst.) Bak.	Fabaceae	Sootallo	D101
76	*Nymphaea nouchali* Burm. F.	Nymphaeceae		D88
77	*Nymphaea lotus* L.	Nymphaeceae		D158
78	*Oryza barthii* A. Chev.	Poaceae		D182
79	*Panicum maximum* Jacq.	Poaceae	Buldarle	D146
80	*Panicum pusillum Hook*.f.	Poaceae	Sutto	D156
81	*Paspalum scrobiculatum* L.	Poaceae	Qortobi	D183
82	*Pennisetum polystachion* (L.) Schult.	Poaceae		D185
83	*Pennisetum trachyphyllum* Pilg.	Poaceae		D138
84	*Pennisetum unisetum* (Nees) Benth.	Poaceae	Migira	D157
85	*Persicaria decipiens* (R.BR.) Kl. Wilson	Polygonaceae	Araba	D13
86	*Persicaria senegalensis* (Meisn.) Sojdk	Polygonaceae	Dengego cheffe	D187
87	*Phoenix reclinata* Jacq.	Arecaeae	Yeho, Meexxi	D119
88	*Pistia stratiotes* C. E. Hubb. & Snowden	Araceae	Mechaaraa	D145
89	****Plantago lanceolata* L.	Plantaginaceae	Qorxobi	D14
90	*Plectranthus punctatus* (L.) L` Herit	Lamiaceae	Siqaaqimee	D10
91	*Polygonum amphibium* L.	Polygonaceae		D21
92	*Polygonum salicifolium* Brouss. ex Willd.	Polygonaceae		D175
93	*Polygonum senegalensis* Meisn.	Polygonaceae		D69
94	*Potamogeton lucens* L.	Potamogetonnaceae		D148
95	*Pseudognaphalium luteo-album* (L.) Hilliard	Asteraceae		D166
96	*Psycnostachys coerulea* Hook.	Lamiaceae	Mata bokkee	D174
97	*Pycnocycla ledermmanii* Wolff	Apiaceae		D150
98	*Ranunculus multifidus* Forssk.	Ranunculaceae		D32
99	*Rhamphicarpa fistulosa* (Hochst.) Benth.	Scrophulariaceae		D163
100	*Rubus stuedneri* Schweinf.	Rubiaceae	Gora	D44
101	*Sacciolepis africana* C.E. Hubb. & Snowden	Poaceae		D106
102	**Satureja paradoxa* (Vatke) Engl. ex Seybold	Lamiaceae	Kefoo sa'aa	D41
103	**Satyrium aethiopicum* Summerh.	Orchidaceae		D90
104	*Scleria hispidula* Hochst. ex A. Rich.	Cyperaceae		D170

105	*Senna obtusifolia* (L.) Irwin& Barneby	Fabaceae	Kishkishi	D164
107	*Sesamum indicum* L.	Pedaliaceae		D123
108	*Sesbania dummeri* Phil. & Hutch.	Fabaceae	Harchaa	D76
109	*Smithia elliotii* Bak.f.	Fabaceae		D126
110	*Solanum incanum* L.	Solanaceae	Hiddii loonii	D17
111	*Sorghum purpureo-sericeum* Hochst. ex A. Rich.	Poaceae	Ageda	D118
112	*Sorghum vulgare* Pers.	Poaceae	Bisinga	D112
113	*Spathodea nilotica* Seem.	Bignoniaceae		D134
114	*Stellaria media* (L.) Vill.	Caryophylaceae		D155
115	*Steresphermum kunthianum* Cham.	Fabaceae	Botoro	D103
116	*Syzygium guineense* subsp. *macrocarpum* (Engl.) F. White	Myrtaceae	baddeessaa	D61
117	*Terminalia brownii* Fresen.	Comberetaceae		D100
118	*Thelypteris confluens* L.	Thelypteridaceae	Geto chefe	D33
119	*Trifolium rueppellianum* Fresen.	Fabaceae		D3
120	*Tristemma mauritianum* J. F. Gmel.	Melastomaceae	Mlean durba	D121
121	*Truimfeta pilosa* Roth	Tiliacaea	Debese	D181
122	*Truimfeta rhomoidea* Jacq.	Tiliacaea		D159
123	**Urtica simensis* Hochst. ex Steud.	Urticaeae	Gurgubbe	D136
124	*Verbascum sinaiticum* Benth.	Scrophulariaceae	Abmokana	D108
125	*Vernonia abyssinica* Fresen.	Asteraceae	Soyamaa	D35
126	*Vernonia auriculifera* Hiern	Asteraceae	Reejii	D147
127	*Zea mays* L.	Poaceae	Boqqolo	D75
128	*Ipomea purpurea* (L.) Roth.	Convolvulaceae		D154
129	*Isolepis costata* A. Rich.	Cyperaceae		D117
130	*Indigofera spicata* Forssk.	Fabaceae	Heennaa	D168

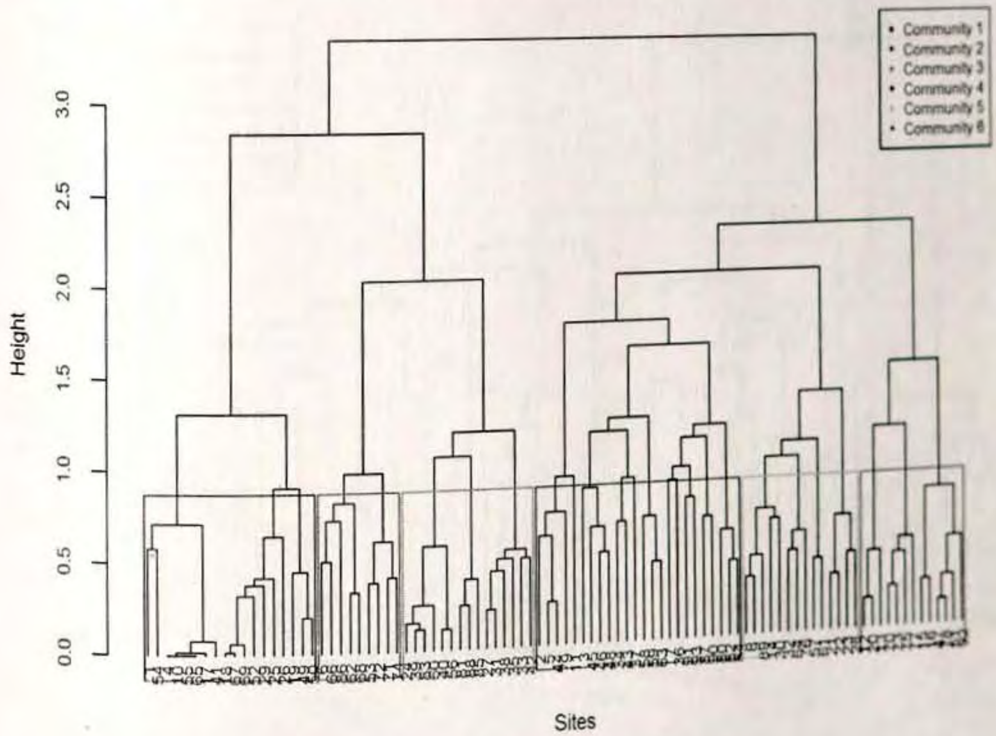
Appendix 2: Environmental variables recorded from the study sites. Plot level hydrogeomorphologic features were rated based on physical evidence of the site or sample plot (e.g., position of the land scape and additional water source) where as drainage was recorded based on water holding capacity of the soil or level of saturation. At each site (sample plot), estimate of disturbance intensity was recorded based on physical evidence of the site characterestics (e.g. soil irregularities, grazing, burning, cultivation, trampling, defoliation and dung) present at the local level.

Hydro-geomorphology		
Category	**Level**	**Remark**
Open waterbody	0	Open waterbody ver sparse acquatic vegetation present
Waterlogged or permanently flooded	1	Permanently flooded emergent or floating plant found
Seasonally flooded	2	Seasonally flooded
Poorly drained	3	Poorly drained area where water may accumulate
Well drained	4	Low lying landscape with well drained soils (sandy)
Wet terrestrial	5	Terrestrial landscape with clay soil
Dry terrestrial	6	Dry terrestrial landscape
Drainage		
Category	**level**	**Remark**
Excessively drained	1	low water holding capacity
Moderately well drained	2	Wet close to surface
Poorly drained	3	Soils wet to the surface most of the time
Standing /flowing water	4	Presence of flowing or standing water
Slope Category		
Category	**level**	**Remark**
No Slope/Flat gradiant	0	Mainly flat at plot location and surrounding landscape
Nearly flat	1	Nearly flat with no distinct aspect
Flat to slight slope	2	low gradiant
Slight to moderate slope	3	Slight to moderate gradiant
Moderate to steep slope	4	Moderate to steep slope gradiant
Steep slope	5	Steep slope
Disturbance at the local level (estimate of disturbance intensity based on physical evidence of the site or sample plot characterestics (e.g. soil irregularities, grazing, burning, cultivation, trampling, defoliation and dung) present at the local level).		
Intensity of disturbance	**level**	**Remark**
No disturbance	0	No evidence of disturbance
Very low disturbance	1	Predominantly undisturbed, some physical evidences
Low disturbance	2	Significant physical evidence
Moderate	3	Moderate level of physical evidences
Highly disturbed	4	high level of evidences
Very highly disturbed	5	Intensively disturbed, Very high level of physical evidences

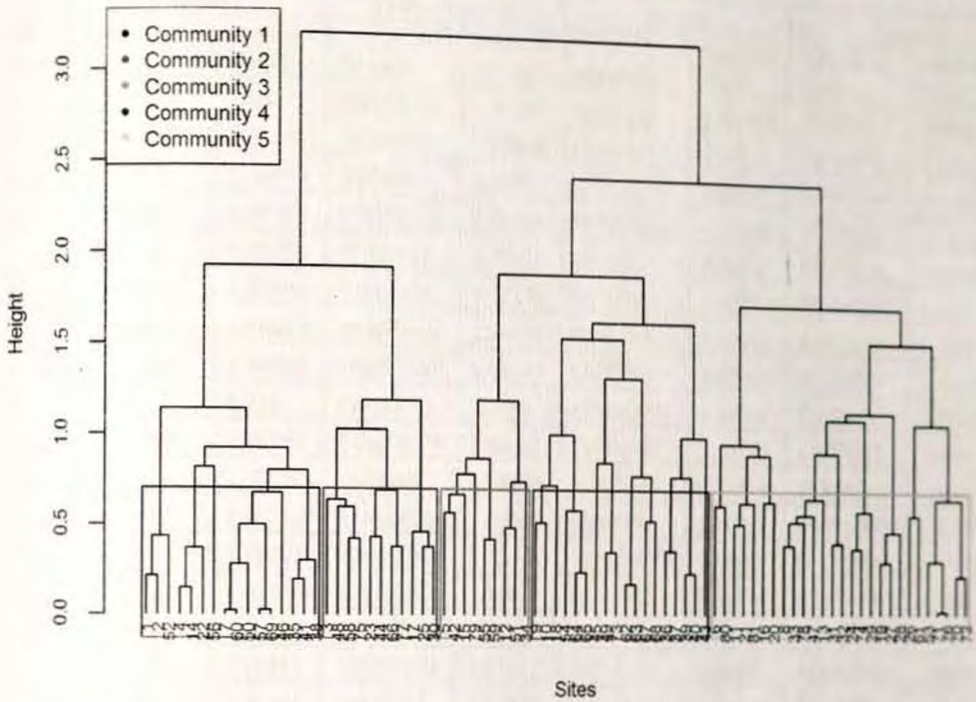
Appendix 3: Dendrograms showing dry season plant community types from the wetlands.



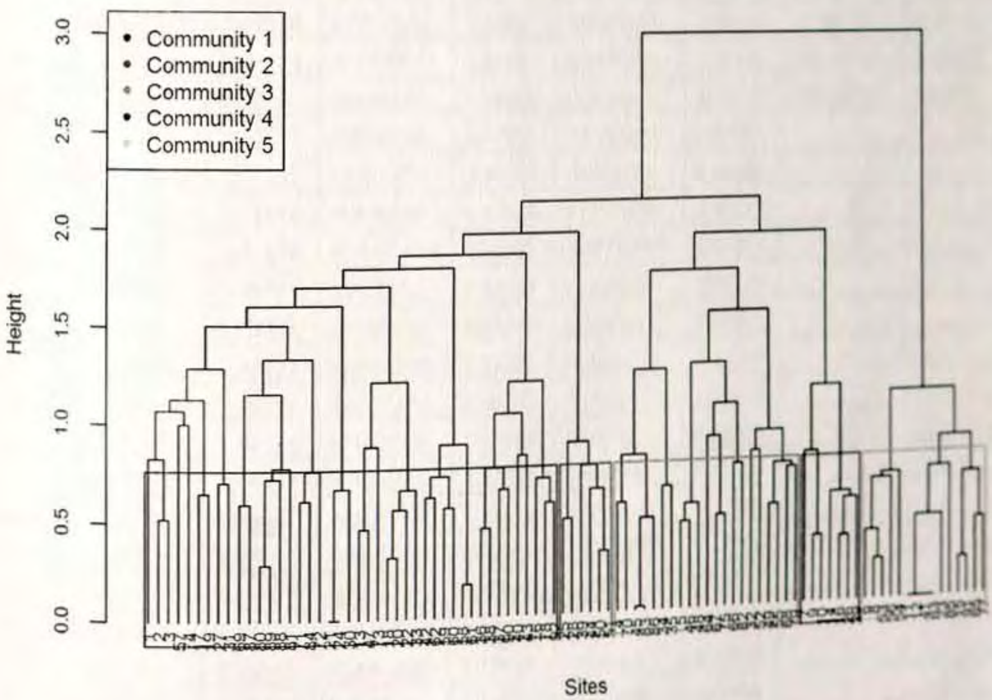
a. Dry season plant community types from Lake Chamo vegetation data



b. Dry season plant community types from Lake Abaya vegetation data.



c. Dry season plant communities from Fincha-Chomen vegetation data.



d. Dry season plant communities from Dabus vegetation data.

Appendix 4: Summary of species list showing rank abundance of top most important species (logsum >1) found in each wetland. Species are coded using the first 4 letters of generic and specific names of plant species given in appendix 1.

	Dabus		Fincha-Chomen		Abaya		Chamo	
Rank Abun	SPecies code	Log(Sum Abun)	SP code	Log(Sum Abund)	SPP code	Log(Sum Abun)	species code	Log(Sum Abun)
1	CYPEPAPY	2.13672	LINDROTU	2.34439	AESCELAP	2.42325	CYNODACT	2.38021
2	VERNABYS	1.91381	PANIHYGR	2.33846	CYNODACT	2.36361	CYPEARTI	2.35025
3	PERSSENE	1.90849	TRIFRUEP	2.08991	LEERHEXA	2.26007	LEERHEXA	2.17026
4	SYZYGUIN	1.89763	CYNODACT	2.05308	TYPHANGU	2.25042	SESBSESB	2.11394
5	GUIZVILL	1.85733	PERSDECI	1.98227	CYPEARTI	2.08636	SOLAINCA	2.00432
6	CYNODACT	1.81954	CYPEDICR	1.97772	EICHCRAS	2.0607	TYPHANGU	1.8451
7	SOLAINCA	1.74036	ERAGTENU	1.96848	PISTSTRA	1.90309	AESCELAP	1.79934
8	THELCONF	1.74036	SHOECONF	1.92942	LEPTFUSC	1.83885	ACACSEYA	1.79239
9	DIGICILI	1.716	CYPELATI	1.8451	CYPESUBU	1.83251	CYPELATI	1.63347
10	CYPEDICR	1.70757	COMMDIFF	1.83251	CYPELAEV	1.79239	LEPTFUSC	1.5682
11	ERIOFATM	1.70757	XYRICAPE	1.79239	ACALRACE	1.72428	IPOMAQUA	1.51851
12	LEERHEXA	1.70757	RANAMULT	1.74036	ECHIPYRA	1.70757	ACHYASPE	1.51851
13	ECHIHISP	1.70757	POLYAMPH	1.72428	CYPELATI	1.6721	LANTCAMA	1.47712
14	FICUSSUR	1.66276	SHOECORY	1.716	FICUSYCO	1.66276	ECHIPYRA	1.38021
15	COMMDIFF	1.66276	THELCONF	1.6721	SOLAINCA	1.5682	PLUCOVAL	1.32222
16	ECHIAMPL	1.62325	FLOSGLOM	1.65321	KIGEAETH	1.5682	ACACTORT	1.30103
17	PISTSTRA	1.60206	CYPEDIGI	1.62325	PLUCOVAL	1.53148	JUSTBIZU	1.20412
18	CYPELATI	1.59106	SATUPARA	1.60206	ACACSEYA	1.51851	ARUNALPI	1.14613
19	ECHISTAG	1.59106	CYPENITI	1.59106	NYMPCOER	1.51851	HIBIVITI	1.07918
20	RANAMULT	1.49136	CYPEESCU	1.5682	SORGVERT	1.49136	NYMPCOER	1.07918
21	VERNAURI	1.49136	BRACBRIZ	1.54407	XANTSTRU	1.49136	ECLIPROS	1.07918
22	ELEOACUT	1.4624	POLYSENE	1.51851	ACHYASPE	1.49136	PASPGEMI	1.04139
23	POTALUCE	1.43136	CYPEATRO	1.47712	BALAAEGY	1.47712		
24	GREWMOLL	1.43136	ERIOFATM	1.44716	CYPEALOP	1.44716		
25	TRIFRUEP	1.43136	TYPHLATI	1.43136	MAYTSENE	1.36173		
26	NYMPNOUC	1.43136	PENNTHUN	1.38021	CROTMACR	1.34242		
27	BIDETERN	1.39794	CYPEELEG	1.34242	FICUOVAT	1.32222		
28	PANIPUSI	1.38021	SPILMAUR	1.34242	SENNDIDY	1.30103		
29	PHONRECL	1.38021	LUDWSTOL	1.32222	ENNEDESV	1.30103		
30	POLYAMPH	1.36173	ASCOCAPE	1.30103	IPOMAQUA	1.30103		
31	NYMPLOTU	1.36173	KYLLODOR	1.30103	ACALFRUI	1.23045		
32	ACHYASPE	1.34242	JUNCOXYC	1.27875	CISSQUAD	1.17609		
33	FLOSGLOM	1.34242	PLECPUNC	1.27875	IPOMERIO	1.17609		
34	TRISMAUR	1.30103	AESCSCHI	1.25527	WOLFARRH	1.17609		
35	PENNTRAC	1.27875	HYDRMANI	1.23045	CORDAFRI	1.14613		
36	SATUPARA	1.27875	GOMPSEMI	1.20412	ALOEOTAL	1.07918		
37	CYPEFISC	1.25527	FIMBCOMP	1.17609	FICUSSUR	1.07918		
38	BIDEPILO	1.23045	ELEUFLOC	1.14613	ERAGJAPO	1.07918		
39	PENNUNIS	1.23045	ECHISTAG	1.07918	ACACMONT	1.07918		

Appendix 5: Photographs illustrating plant community types from study areas.

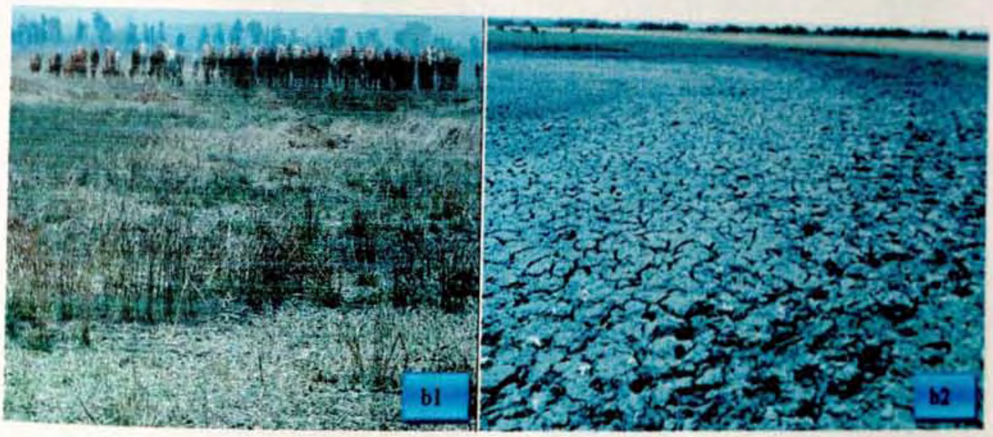

(a) *Cynodon aethiopicus-Solanum incanum* (Chamo) (b) *Leersia hexandra* community (Lake Chamo)


(c) *Lindernia rotundata-Trifolium rueppellianum-Cynodon aethiopicus* (Fincha-Chomen) (d) *Cyperus dichroostachyus* (Dabus)


(e) *Eriochloa fatmensis-Cyperus latifolius* (Dabus) (f) *Schoenoplectus corymbosus-Cyperus latifolius* (Fincha-Chomen)

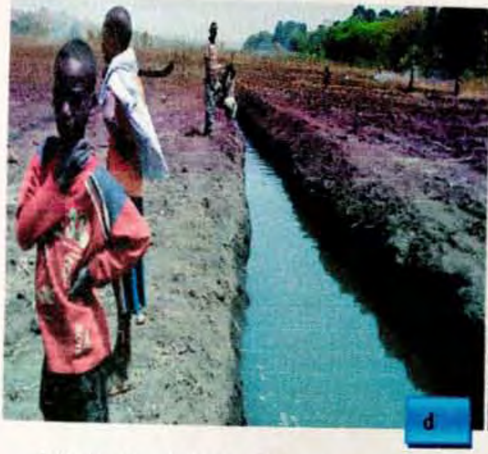
Appendix 6: Photographs illustrating some causes of vegetation loss in studied wetlands

(a) Dabus as dry season grazing area for wildlife: Hippos (a1 & a2) and warthogs (a3) and highly grazed area (a4)



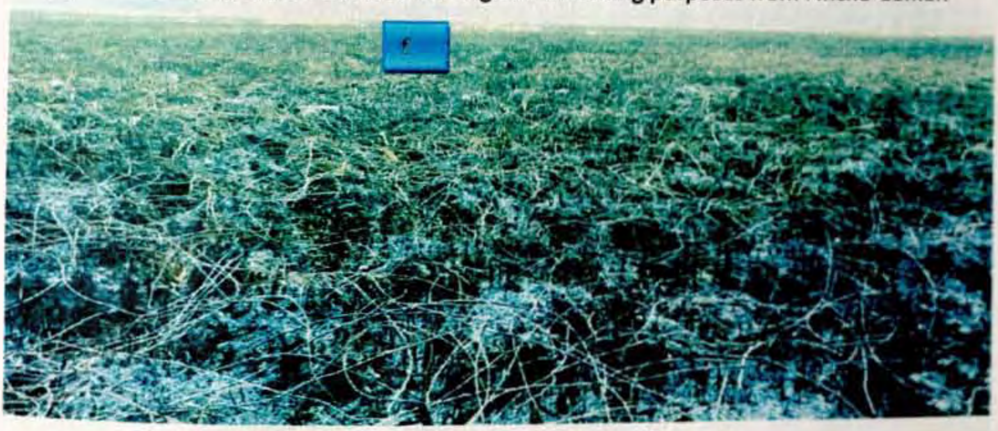
(b) Overgrazing by livestock (b1) and soil compaction (b2) in Dabus

(c) Boat construction for fishing and associated plant species loss (*Aeschynomene elaphroxylon*) in Lake Abaya and Chamo



(d) Wetland drained for expansion of agriculture in Fincha-Chomen

(e) Wetland plants collected for roofing and thatching purposes from Fincha-Comen



(f) Intensively burned vegetation (*Persicaria senegalensis)* in Dabus.

Appendix 7: Fauna of the wetlands.

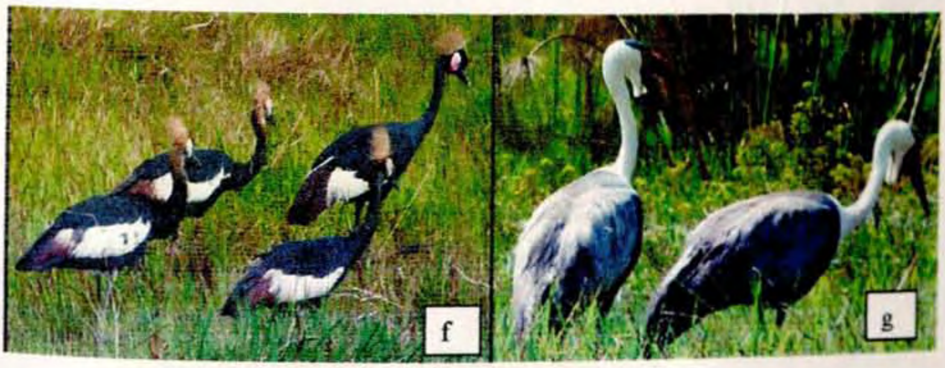
The shoreline vegetation of Abaya and Chamoe Lakes is an important spawning area for Crocodiles, habitat for migratory bird populations and grazing site for hundreds of hippos. A stretch of grassland vegetation on the northwest shore of Lake Chamo is locally known as "Crocodile Market", where hundreds of hippos gather together along with crocodiles and wetland birds. There is a Crocodile ranch at south end of Lake Abaya near Arba Minch town. As desiginated by BirdLife International (2001), Dabus wetlands were an Important Bird Area for Ethiopia. The vulnerable Wattled Crane (*Bugeranus carunculatus*) and the near threatened Lesser Flamingo (*Phoenicopterus minor*) were very common in the area. There is also an impòrtant population of rare and restricted Wattled Ibis (*Bostrychia carunculatus*). Shoebill (*Balaeniceps rex*), uncommon to rare status, bird observed in this wetland. It is an endemic to Africa, which usually inhabits papyrus swamps. The wetlands of Dabus also support hundreds of hippos. Some of the fauna observed in wetlands were shown in the following illustrations.

(a) The Crocodile ranch (Lake Abaya near Arba Minch town) (b) Wetland birds feeding and nesting on wetlands (Dabus).

(c1) Fish collected form Abaya (c2) and Dabus and (c3) Shoebill (*Balaeniceps rex*) from Dabus

(d) Hundreds of birds and "Crocodile market" at Lake Chamo

Dabus (e1) and Lake Chamo (e2) support hundreds of hippos



(f) Black-crowned crane (*Balearica pavonina*) and (g) Wattled crane (*Bugeranus carunculatus*) from Dabus wetland