ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

AN ECOLOGICAL STUDY OF VEGETATION AROUND LAKE ABIJATA

BY

TOLCHA REGASSA

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TOLCHA REGASSA

A thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the award of Masters of Science in Dryland Biodiversity under the Department of Biology, Faculty of Science.

Approved by Examining Board

Name	**Signature**
________________________________, **Examiner**	___________________
________________________________, **Examiner**	___________________
Dr. Tamrat Bekele, Advisor	_____________________
Prof. Zerihun Woldu, Advisor	______________________
_____________________, Chairman	_____________________

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ABSTRACT

Ecological study of the vegetation around Lake Abijata was carried out within the principal objective of describing the plant communities of the study site. In order to determine the plant communities five transects were laid from the shoreline to the open land. Along the laid transects, different sized quadrats 1 m^2 (for herbs), 25 m^2 (for shrubs) and 100 m^2 (for woody species) were systematically laid to collect floristic data following a 1-9 modified Braun Blanquet scale (van der Maarel, 1979). All together a total of 143 quadrats were sampled from the study site. Soil samples were taken from the depth of 0-20 cm using soil auger and analyzed for soil pH, electrical conductivity, cation exchange capacity, soil texture and bulk density.

Data were analyzed using various multivariate methods, inter alia, TWINSPAN (Two way indicator species analysis), CCA (Canonical Correspondence Analysis) and DCA (Detrended Correspondence Analysis). A total of 97 plant species belonging to 28 families were identified. The TWINSPAN out put showed that there are 6 different plant communities.

The distribution patterns of plant species in the study area shows horizontal stratification with the strata being dominated by its dominant species. The distribution patterns of the plant species in the area appears to be governed by soil as the most important environmental factors.

1. INTRODUCTION

The Ethiopian rift is characterized by a chain of lakes varying in size, hydrological and Hydro geological setting. Some of the lakes and Feeder Rivers are used for irrigation, soda abstraction, commercial fish farming, recreation and support a wide variety of endemic birds and wild animals. Few lakes shrunk due to excessive abstraction of water; others expanded due to increase in surface runoff and groundwater flux from percolated irrigation water. Excessive land degradation, deforestation and over-irrigation changed the hydro metrological setting of the region. The chemistry of some of the lakes has also been changed dramatically.

The rift-valley lakes (Abijata Lake is one of these) are a chain of permanent lakes lying entirely in the southern part of the Ethiopian rift valley. Most of the Ethiopian rift-valley lakes are very productive, containing indigenous populations of edible fish and supporting a variety of aquatic and terrestrial wildlife. Some of these lakes are being used for commercial fisheries, irrigation, recreation, and some industrial purposes.

Drainage areas of the Ethiopian rift valley regions have been changed by different natural (e.g. drought) and anthropological impacts. Zinabu Gebre-Mariam (1998) discussed some of the anthropological factors in the area. These are clearing of forests, animal grazing, and other reductions in the vegetation of the catchment areas of the Ethiopian lakes, which have expanded considerably during recent years increase. Deforestation, which results from the usage of wood for fuel and construction and from the population-driven need to increase cultivable land, poses a serious problem. Most of the factors that encourage soil erosion (depleted forest, inadequate plant cover, organically poor soils, improper farming methods, etc.) are very common in Ethiopian rift valley region.

Irrigation is another major threat to the very existence of the Ethiopian rift valley lakes. Small-holder farming and state farms in the drainage areas of the Ethiopian rift-valley lakes have modified the catchment areas of the lakes and have contributed to enhanced nutrients and particulate run-off, especially when the grasslands are overgrazed and the fields are tilled or fertilized. The irrigation scheme that is being used for farms around Lake Zwai has had a considerable effect on the water level. Since the irrigation in this area is a year-round process, its effect on the water level is magnified, especially during times of low precipitation and high evaporation (Zinabu and Elias, 1989). Several rivers that flow into one or more of the rift-valley lakes have been diverted for irrigation. The rivers Meki and Katar and the Bulbula and Gogessa rivers, which flow into Lake Zwai and Lake Abijata, respectively, are being used for irrigation. This practice has caused water level subsidence in both lakes because of the reduced inflows.

Urbanization and human settlement in close proximity to the Ethiopian lakes are among the greatest potential causes of changes in Rift valley region of Ethiopia. Although there is very little indication of acute cultural pollution in the Ethiopian lakes at the moment, the potential problems deserve some attention here. The growing population and industrialization of the cities and towns (e.g. Ziwai, Meki, Bulbula, etc) can have potentially serious consequences on the lakes. It is possible that domestic and industrial wastes may find ways into the lakes.

Another important human impact on the rift valley region of Ethiopia is industrial uses of water. There are not many industrial projects on the Ethiopian lakes at the moment. It is, however, possible that such ventures will soon start and their impacts may be severe. The soda ash extraction plant on Lake Abijata is a good indicator of what can be brought about by industrial uses of water from the lakes. It has been already mentioned that the water level of Lake Abijata has declined as a result of the diversion of its inflows for irrigation. This loss of water from Lake Abijata has been exacerbated by certain activities of the soda ash extraction plant, such as pumping of water from the lake. The relatively shallow depth and terminal position in the drainage area make Lake Abijata rather vulnerable. The fish and wildlife populations supported by the lake have already been affected. Although the direct and immediate benefits of such development activities are demonstrable and not in question, one must question the ecological impacts of initiating undertakings like the one on Lake Abijata.

On the other hand the terminal lake Abijata has shown a considerable increase in ionic concentration since 1961 (Zinabu, 1998). Changes in phytoplankton composition also seem to have taken place in Lake Abijata: A dominant population of *Spirulina* species reported from Lake Abijata in the 1960s (Wood and Talling, 1988) replaced by dominant phytoplankton, *Anabaenopsis abijatae* (Elizabeth and Willen, 1996). Anecdotal information from local people and close observation of the shore line of Lake Abijata suggest that the water in this lake has receded significantly in the last three decades. Although the soda ash extraction plant on Lake Abijata may have increased the evaporation rate of the lake water in the last 10 years or so, diversion of the inflows for irrigation purposes and flushing from deforested and heavily grazed catchment may also have contributed to the decrease in the water level and the increase in the concentrations of ions (Zinabu and Elias, 1989).

The major changes in the rift valley are related mainly to recent improper utilization of water and land resources in the lakes catchment and direct lake water abstraction aggravated intermittently by climatic changes. These changes appear to have grave environmental consequences on the fragile rift ecosystem, which demands extremely urgent needs of integrated basin-wide sustainable water management.

All the above factors might contribute the diminishing of the Abijata Lake. As this happens the vegetation encroach following the diminishing lake. This paper addresses the major environmental factors that are responsible for the encroachment of the different plant species in different horizontal stratification around the lake laying the transects from the lakeshore to the mainland.

2. LETERATURE REVIEW

2.1 Species along Environmental Gradients

Vegetation may be defined as an assemblage of plants growing together in a particular location and may be characterized either by its component species or by the combination of structural and functional characters that characterize the appearance, or physiognomy, of vegetation (Goldsmith *et al*., 1986). Ecologists differ in their opinions of how the definitions of vegetation can be interpreted when confronted with real communities. Some ecologists, described as phytosociologists, think that plant communities can be identified and classified as discrete units just like species and genera. Plant species are the building blocks of the plant communities (Walter, 1973) that together constitute the vegetation of the different zones.

Vegetation description is used for the recognition and definition of different vegetation types and plant communities known as the science of phytosociology. The science of phytosociology is used in the mapping of vegetation communities and types, and studies relationships between plant species distributions and environmental controls (Kent & Coker, 1992). The most recent grouping of plant communities according to similarity in floristic composition proceeds from confirmed observation that every species, indeed every race, has a definite greater or lesser, indicator value. This is the floristic system. The floristic composition or a list of species, life form composition and structure of vegetation are a necessary basis of all ecological work (Kershaw, 1973). In this system the species are used as signs of certain ecological relations. Similarly, the combination of species of two communities shows similarity in their conditions in the widest sense (Braun-Banquet, 1965). Since we combine floristically related communities into higher units, we are uniting, by floristic characteristics, units that should be united also on ecologic and historic grounds.

Each region has a particular pattern of spatial heterogeneity, biological history, and temporal heterogeneity imposed by climate and its interaction with biological processes. The effect of environmental conditions and disturbance regimes on the patterns that occur on different patches within a landscape may create a constant change in the value of species composition and diversity.

The effects of major discontinuities of the environment on vegetation are usually well marked and, though such reactions of the vegetation result in patterns in the true sense of the word are obvious as a change of floristic composition. It has become increasingly evident that extremely small variations of an environmental factor(s) operating over quite large areas will produce a corresponding variation in the vegetation (Kershaw, 1973). Thus environmental pattern is developed in vegetation in response to a general and overall variation of one of the major environmental factors and produces a pattern of density distribution.

A careful analysis of vegetation is a means of revealing important information about other components of the ecosystem (Goldsmith *et al.*, 1986). Vegetation study could also help and promote to select and employ the appropriate conservation and management plan for sustainable use of ecosystems (Kershaw, 1973). Floristic data are relevant for establishing the present situation for environmental impact assessment and for monitoring changes in ecosystem quality in terms of changing species composition.

The structure and composition of vegetation is often a consequence of environmental gradients, which can be defined as a change in the value of a particular parameter, such as temperature, soil pH, soil moisture or species composition over space (Whittaker, 1975). Kershaw (1973) defined the structure of vegetation by three components: the vertical arrangement of species, i.e., the stratification of the vegetation; the horizontal arrangement of species, i.e., the spatial distribution of individuals; and finally, the abundance of each species. The latter component of vegetation can be expressed in several ways, ranging from a direct count of the number of the individuals in an area to the dry weight of vegetable material produced in a given area. This is especially true in horizontal distribution of species in the community. A gradient describes a species assemblage that gradually changes across the area. Gradients of gradual change in species diversity or species composition are common. On most landscapes the pattern of zonation is defined by the visually dominant species (Whittaker, 1975; Huston, 1994).

Any one organism has a limited range of environmental conditions in which it can exist, and within those, certain optimum conditions that suit it best. Plants occupy a given environment necessary for them and modify it, altering its physical structure, changing nutrient availability, providing new microclimates. Such change may mean that the new environment suits the original inhabitants less well than it did, and/or that it now becomes more suitable for species, which previously were unable to invade the system. Thus either the environmental conditions become so altered that the original can no longer exist within the community and becomes extinct-with its place later taken over by new immigrant species, or the new colonizer, better adapted to the changed environment, actively displaces the original colonists through competition.

In reviewing the evidence on species responses, three types of environmental gradient have been recognized. First, indirect environmental gradients, in which the environmental factor used to order the observations does not of itself, have a direct physiological influence on plant growth. Elevation is an example of such a gradient and aspect is another. Such variables may show strong correlation with species performance in some areas and none in others depending not on a change in the limiting factor for plant growth but a change in the correlation of the limiting factor with the environmental variable. Secondly, direct environmental gradients, where the environmental factor has a physiological influence on plant growth but is not a resource for plant growth for which exploitative competition might be take place. PH is an example; it has a major impact on plant growth by modifying the availability of various nutrient resources, through known physio-chemical processes. And thirdly, resource gradients, where the environmental variable is actually an essential resource for plant growth, nutrients.

Plant communities are the collection of the plant species that grow together in a particular location that show a definite association or affinity with each other (Kent and Cooker, 1992). Some species tend to occur together, because they tend to share certain environmental requirement. Some species are found growing together in certain locations and environments more frequently than would be expected by chance. This comes out in the view that species must have similar requirements for their existence in terms of environmental factors such as light, temperature, water, soil nutrient, salinity, etc. These factors shape the distribution and adaptation of the plants. Changes in one environmental condition usually bring about changes in others. Increasing soil moisture alters the availability of nutrients and variations in the amount and source of organic matter in the soil create parallel gradients of acidity, soil moisture, and available nitrogen. Such factors often interact in complex ways to determine the distributions of plants.

Soil characteristics are of prime importance to plant distributional patterns. Near the lakeshore soil is inundated. Soil inundation and partial or total submergence of vegetation drastically affects gas exchange in both plant and soil; soils not only become anoxic, their chemistry is altered and becomes, to varying degrees, deleterious to plants (Clarke and Hannon, 1970; Snow and Vince, 1984; Armstrong *et al*., 1985; Marschner, 1986). A direct result of water logging is reduction of soil aeration. Soil aeration and the consequences of soil anoxia have thus come to be regarded as major factors affecting plant performance and the zonation of vegetation. The effects of nutrient concentration may interact with aeration (Loach, 1966). The area that has highest nutrient levels has good aeration. Plant growth is greatest in the most nutrient rich site and least in the most nutrient deficient, areas near the lake. The combined effects of increased water supply and poor aeration markedly affects both the structure and floristic composition of the vegetation (de Selm and Shanks, 1967). Harris (1960) concluded that there are four possible causes of poor plant growth in soils: toxicity due to salinity, limited aeration, difficulty of the rooting moisture and the mechanical difficulty of the root forcing its way through the dense soil.

Associations between abiotic variables and patterns of species distribution and abundance are a major preoccupation of community ecologists (Ellison *et al.*, 2000). In many habitats, this association is manifest in discrete zones of vegetation. Identifying patterns of species distribution and abundance and determine the mechanisms underlying these patterns have been, and continue to be, also major preoccupation of community ecologists. Zonation in mangrove forests often has been attributed to the responses of individual species to variation in degree of tidal inundation, salinity or other measurable edaphic gradients that vary predictably across the intertidal, although it may be at least partially determined by biotic factors (Ellison *et al.*, 2000).

Snow and Vince (1984) indicated that zonation of species along an environmental gradient may arise if: each species is physiologically restricted to a different portion of the gradient; each species performs best in a different portion of the gradient-however, tolerance ranges are sufficiently broad that species would grow in other habitats where it not for inadequate dispersal, the presence of competitively superior species, or herbivores, or a combination of these; and all species prefer the same portion of the gradient-species are displaced along the gradient according to their breadth of tolerance, dispersal, competitive abilities, and susceptibility to herbivory.

There is an obvious zonation as species occupy different positions relative to the water level. This zonation suggests that the gradients of factors varying with relative height (moisture, particle size, etc.) have a major influence on shoreline plants and their associations (Keddy, 1982). The range of relative heights which a species occupies on a particular shoreline (or in a particular transect) can then be treated as one measure of the niche it occupies. On a very local scale, there is great variation in species composition and species richness in lakeshore vegetation. Keddy (1982) indicated that compared with latitudinal and altitudinal variation, the variation within lakes is less likely to be confounded by climate, geological history or chance events of dispersal. Much of the within-lake variation can be attributed to variation in the wave-energy regimes of the shoreline concerned.

2. 2 Species Diversity and Community Composition

Ecologists have measured diversity either by estimating species richness (number of species) in an area, or by one or more indices combining species richness and relative abundance within an area. Richness and diversity have commonly been described as a characteristic property of a putative homogeneous community and indicative of its organization (McIntosh, 1967). Species richness increases as a function of ecosystem size and appears to increase even within established communities, over time (Putman, 1994). Moreover, diversity is a function of time: all communities tend to diversify with time; therefore older communities will be to more species rich than young ones. Attempts to classify ecological units are based on identification of the species, which occur in them along with a description of the physical characteristics of the area. Most terrestrial ecosystems are generally identified on the basis of plant communities that are areas with similar plant species composition and structure. The basic principle underlying this is that different species may habitually be closely associated with each other over a wide geographical range.

Although a characteristic type of plant community will inhabit each clearly distinct type of habitat, the species composition may differ widely, depending upon the source of plants available to populate the area. The concept of diversity is particularly important because it is commonly considered an attribute of a natural or organized or is related to important ecological processes (McIntosh, 1967). Ecologists also use species diversity as one important measure of the structural heterogeneity of a community. There are many ways a community can be diverse in species. They may vary in number (richness) of species, degree of dominance by one or a few species, relative abundance of all species (evenness), number of rare species, number of nonnative species, vertical stratification of species, horizontal patchiness, number of growth or life forms, and so on. Diversity has been said to increase in a successional sequence to a maximum at climax, to enhance community stability, and to relate to community productivity, integration in evolution, niche structure, and completion (McIntosh, 1967). Species diversity measurements are used to help interpret mechanisms operating in the community.

The community is one of the key concepts in the science of vegetation, and data in all branches of the subject should be treated in the community context (Poore, 1962). Ecological findings should be related to communities. But every description is an abstraction from the available data. Braun-Blanquet, one of the major early exponents of phytosociology, saw the community as a social unit. He stated that every natural aggregation of plants is the product of definite conditions, present and past, and can exist only when these conditions are filled (Braun-Banquet, 1965). He went on to describe that the phytosociologist’s aim is to catalogue and describe the plant communities of the earth, to discover their causal explanation, to study their development and geographic distribution, and to arrange them according to a natural system of classification. Other ecologists see the vegetation, not as a patchwork quilt of distinct classifiable communities, but as a continuously variable continuum. Vegetation study cannot, therefore, be by identification of a community type and its boundaries, but by mapping the alteration in the vegetation across a wide area of environmental changes.

Whittaker (1975) distinguished three different kinds of species diversity along certain environmental gradient that he called alpha, beta and gamma diversity. Alpha diversity refers to the number of species within a sample area. Beta diversity describes the difference in species composition between two adjacent sample areas along a transect. Beta diversity is low when the overlap between the species composition of two quadrants is high, and is highest when the samples have no species in common at all. Gamma diversity describes regional differences in species composition (e.g., the difference in species composition between comparable habitats on two adjacent mountain ranges). Areas with the very highest levels of species richness are those where there are many species per quadrant, but no two quadrants on a transect area alike in their species composition. In regions of the lowest species richness there are few species in any sample, and the vegetation is spatially monotonous. Even if the building blocks are not identical, extreme environmental conditions can lead to similar life forms.

To a certain extent plant community types can be based on the occurrence of characteristic species (or taxonomic groups) of plants. The classification of communities on a taxonomic basis is difficult because of the variation in species composition from one community to another of the same general type and because of many irregularities in occurrence (Clarke, 1954). Furthermore, the composition of a community depends not only upon which species will grow under the conditions of the habitat but also upon which species happen to have been successfully distributed to the area.

Communities inhabiting distinctive and commonly occurring habitats are the most easily recognized, and their composition and interrelationships have been more extensively studied than others. A community of this kind is made up of a characteristic, but flexible, assemblage of species without necessarily containing any species that is exclusive to it (Clarke, 1954). Certain types of species invariably occur in a community of a certain kind, but the individual species may vary widely from place to place.

It is the common experience of plant ecologists that vegetation is not a random assemblage of individuals of many species, but that plants are associated in communities, which have a definite structure and often a regular specific composition. Only the species, which are adapted to a particular habitat, are selected from the available propagules of the total flora of a region, and by mutual compatibility in requirements for nutrients and light (Poore, 1962). Soil structure, soil fertility, moisture conditions and aspect influence the microdistribution of plants. Patterns of light shade shape the development of understorey vegetation. Runoff and small variations in topography and microclimate produce well-defined patterns of plant growth. Grazing animals have subtle but important effects on the spatial pattering of vegetation, as do abiotic disturbances such as wind throw and fire. Among plants opportunities for environment, growth, reproduction, and survival vary spatially as do variations in biological interactions such as competition for space. The mode of plant reproduction and availability of propagules over time also affect vegetation pattern. Plants with wind-dispersed and animal-dispersed seeds have a wide distribution across the landscape than plants with heavy seeds. Vegetative or clonal reproduction produces distinctive clumps or patches of certain plants in an otherwise homogeneous environment. Allelopathic effects and shading lead to the suppression of some plant species and to the development and growth of others.

Communities may be large or small. Some may cover thousands of square kilometers. Others communities, such as those occupying relatively uniform swamp, desert, or lake habitats, may have dimensions in hundreds of kilometers. The number of species and the population abundance in communities also vary greatly. While maintaining the necessary quantitative relationships among the species in the ecosystem, the inhabitants of an area often include a wide range of densities. Furthermore, one, a few, or many species, may represent each component in the ecosystem. Habitats with extreme conditions generally support few species and relatively few individuals of species. Under more equable climates larger numbers of species generally become interrelated in community groups; each species is usually rather meagerly represented, but sometimes the abundance of certain species is great.

Few complete enumerations have been made of the plant species in even the simplest situations and none in complicated habitats. The complex ecosystems of temperate and tropical terrestrial areas are particularly difficult to analyze, but some idea of the number and diversity of the living components may be obtained from existing studies of portions of the biota.

Another observation in regard to community composition is that the species present for the most part belong to different genera. In many communities each genus is represented by one or more species; in others certain genera are represented by several species. Rarely are more than a few species of a genus found in the same communities (Clarke, 1954).

To make a census of the inhabitants of a diversified natural community and to ascertain the role of the various species in any complicated ecosystem is exceedingly difficult. Such tasks require the combined efforts of at least several taxonomists and ecologists competent to deal with the various segments of the biota. Investigators confining themselves to restricted categories of plant life have for the most part carried out detailed studies of the inhabitants of specific habitats. To obtain an idea of the total assemblage of plant species making up community and their integrated activities, it is usually necessary to piece together the results of several investigations. The reader may obtain rather complete information on the composition of the entire biota of certain specific areas by reference to the collaborative reports of members of expeditions, of government surveys, and the field research laboratories.

2.3 Horizontal Heterogeneity/Stratification of the Community

Wherever we travel, we find that the environment alters from place to place, indeed often from step to step; correspondingly, the vegetation alters in both species composition and in the frequency of the component species. Many communities exhibit a structure, or recognizable pattern, in the spatial arrangement of their members. A community may be divisible horizontally into “sub communities”-that is, units of homogeneous life-form and ecological relation. According to Crawley (1997) there are two extreme spatial structures in plant communities. In the first case there are distinct zones of different plant species, as we might see in the emergent vegetation surrounding shallow lakes. In the second, there are indistinct patterns, one grading imperceptibly into the other, as we might find in a transect up to forested mountainside.

Smith (1990) indicated that horizontal heterogeneity in plant species results from an array of environmental influences. For every combination of soil, climate, altitude, slope and aspect there will be one species that grows better than any other, so that it produces more seeds or occupies more space by vegetative spread (Crawley, 1997).

Where the physical features of the biotope /habitat are sharply delineated and where these features exert primary control over the occurrence of the plants, a correspondingly abrupt change in the flora takes place. An outcropping of rock in a forested region, for example, will result in an abrupt shift in the vegetation from trees to mosses or lichens.

Sharp limits to a community or its subdivisions may sometimes be found in situations in which the climatic or edaphic conditions appear to change only slowly. Such a result occurs when alterations in the environment favor the survival of a new controlling species; it is seen particularly among stands of routed land plants but is also apparent in the zonation of sessile plants in the tidal zone (Clarke, 1954). Among the terrestrial plants, for example, the competition for light, water, and nutrients may be so keen that, at the point in the environmental gradient at which the conditions favor a different dominant species, the new species will take over completely, chocking out the first species and producing a rather distinct line between the areas dominated by the two species. In approaching Lake Abijata, for example, the acacia trees often give way rather abruptly to a zone of shrubs. Beyond this zone are clearly marked zones of low shrubs, sedges, or grasses, and the last of these gives place to the other emergent plants at the lake margin. This distinct zonation exists in spite of the fact that a quite uniform gradation in environmental gradients.

The step-like occurrence of the vegetation within the community, or between communities, may react on the environment to impose a zonation on some of the physical features of the habitat, and this in turn may cause a zonation in the minor constituents of the community. Even without this effect, however, the dependence of certain plants upon specific kinds of vegetation for food, shelter, or other needs produces abrupt changes in the distribution of the minor inhabitants corresponding to that of the dominating species. For variety of reasons the boundaries of certain plant community are clearly distinct, but in many other instances one community gives place gradually and irregularly to another.

The transition zone of tension, ecotone, between communities presents a situation of special ecological interest. The border between forest and grassland, the banks of a stream running through a meadow, or the boundaries between any other communities on land furnish illustrations of ecotones. In this transition zone of tension the outposts of each community are maintaining themselves in environments that are increasingly unfavorable. The transition may result chiefly from a struggle with physical conditions or from a direct competition between certain species in each community. At the border between a shrub community and a marsh, for instance, the shrubs may compete directly with marsh reeds for light, nutrients, or other necessities of life in such a way that one type of plant gives way completely to the other. In such a situation and in areas where controlling physical factor change rapidly the transition between communities is abrupt and the ecotone is correspondingly narrow. In other circumstances the two communities may interdigitate to a considerable extent. At the edge of a forest individual trees may pioneer into a scrub community, and the scrub species will invade the margin of the forest as far as they are able to survive. When one community gives way only gradually to the other community, a wide ecotone results (Crawley, 1997).

In the ecotone area the conditions of temperature, moisture, light, wind, and other physical influences are different from, and usually intermediate between, those existing well within either of the bordering communities. These or other conditions may be superior in the region of ecotone for certain species. As a consequence various kinds of plants not occurring, or relatively rare, in the bordering communities may become abundant in the ecotone. Shrubs typically grow in profusion at the forest edge. At the margin of a lake willows and cattails thrive in the transition between land and water.

These species favored by the special conditions of the ecotone join with the outpost representatives of the principal inhabitants of the bordering communities in populating the ecotone. The species occurring in the ecotone may thus form a distinct functional community of their own. It must be remembered, however, that the ecotone inhabitants owe their existence to the presence of the particular conditions on each side and that the ecotone assemblage would disappear, or be considerably modified, if the bordering communities or conditions were removed or seriously changed. As a rule the ecotone contains more species and often a denser population than either of the neighboring communities, and this generality is known as the principle of edges.

According to Clarke (1954) two general types of situation exist in regard to the manner in which the community as a whole is controlled. In the first type the presence of one or a few species appears to exert a major effect in determining what other species occurs in the area. In the second type the physical features of the habitat tend to control the occurrence of most of the species present more directly and independently. No sharp division exists between these two general conditions. An acacia forest will serve as an illustration of the first category. Here the general conditions of soil and climate are such that acacia trees can grow in abundance and the presence of this species secondly creates a suitable habitat for a large number species of plant. Sometimes two or more species, usually of the same general life form, exert a joint major control.

In the acacia community the acacia trees are chiefly responsible for the conditions of light and moisture within the forest. They modify the temperature and affect the structure of the soil together with its acidity and chemical composition. The acacia trees thus influence the species of shrubs, herbs, and cryptogams that will grow on and in the forest floor. In the second general type of control over the community the physical features of the environment tend to influence the principal species independently.

In many communities one species is particularly conspicuous because it is the largest or the most numerous. This species is often called the dominant. Occasionally two or more species share the honors in respect to dominance. Very frequently the species that is dominant in conspicuousness also appears to exert a controlling influence over the other members of the community, but sometimes a less conspicuous species may have a predominant influence on the inhabitants.

Different scholars have different views about plant communities. Clements (1916) saw plant communities as clearly recognized and definable entities which repeat themselves with great regularity over a given region of the Earth's surface. This is known as "organismic concept". He argued further that plant communities could not function without all its organs present. He described plant communities as discrete units with sharp boundaries. This view is reinforced by the conspicuousness of many dominant vegetation types. On other hand Gleason (1926), saw that all plant species distributed as a continuum. He argued that, plant species respond individually to variation in environmental factors and those factor vary continuously in both space and time. He suggested that the community, far from being a distinct unit like an organism, was merely a fortuitous association of organisms whose adaptations enabled them to live together under the particular physical and biological conditions found at a particular location. Every species has different distribution or tolerance range. The success of the species depends on the combination of environmental factors on that site. This was viewed as "individualistic” concept of the plant community.

Clements’ and Gleason’s concepts of community organization predict different patterns in the distribution of species over ecological and geographical gradients (Ricklefs, 1990). On one hand, Clements believed that the species belonging to a community were closely associated with each other; the ecological limits of distribution of each species coincided with the distribution of the community as a whole. This type of community organization is commonly called a closed community. On the other hand, Gleason believed that species was distributed independently of others that co-occurred in a particular association, an organization referred to as an open community. We would draw the boundaries of an open community arbitrarily with respect to the geographical and ecological distributions of its component species, which may extend their ranges independently into other associations of species.

Closed communities represent natural ecological units with distinct boundaries. The edges of the community, ecotones, are points of rapid replacement of species along the gradient. We may arbitrarily delimit an open community at some point.

The separate concepts of open and closed communities both apply to associations of species in nature. We observe distinct ecotones between associations under two different kinds of circumstances: when there is an abrupt change in the physical environment-for example, at the transition between aquatic and terrestrial communities, between distinct soil types, or between north-facing and south-facing slopes of mountains-or when one species or life form so dominates the environment of the community that the edge of its range signals the distributional limits of many other species. At the boundary between grassland and shrub land, or between grassland and forest, sharp changes in surface temperature, soil moisture, and light intensity result in many species replacements. Sharp grass-shrub boundaries occur because when one or the other vegetation type holds a slight competitive edge, it dominates the community. Grasses prevent shrub seedling growth by reducing the moisture content of the surface layers of the soil; shrubs prevent the growth of grass seedlings by shading them out.

Ramakrishnan and Kumar (1976) states factors that control plant species development on a new environment and hence the species diversity. These include availability of seeds for colonization, the nutrient content of the soil, coupled with moisture conditions at the time of seed dispersal, and subsequent management of the succession, especially the incidence of grazing.

2.4 Vegetation Characteristics

Vegetation characteristics have been described in various ways depending on the study interest and objectives.

2.4.1 Physiognomic approach

Physiognomy is a morphological characteristic of vegetation. It is primarily determined by growth-form and life-form of the dominant or co-dominant plants. As it is visually recognized and distinguished, it has been extensively used to characterize vegetation. Indeed, physiognomic classification is readily applicable to any kind of vegetation of the world, even in regions where the flora is not well known, or even if a researcher is not well acquainted with the flora. The term “formation” became widely accepted as a physiognomic unit and was extensively used in fields of ecology, biogeography and vegetation science.

The physiognomic approach provides a fast and efficient means to describe and characterize vegetation, as it does not require much floristic detail about the vegetation. It is especially effective in regions where the flora is not thoroughly known. In other words, the physiognomic characterization may be carried out fairly routinely if some guidelines are provided. It is, therefore, particularly useful for conducting a reconnaissance type of vegetation survey to cover large geographical areas in a limited time. The approach is not very effective in detecting special and temporal changes of vegetation in detail unless such changes are great enough to substantiate a shift of formation type.

2.4.2 Floristic approach

The floristic approach may be represented by the phytosociology of the Zürich-Montpellier school. It developed from the physiognomic approach in the late 19th and early 20th centuries in central Europe. The approach emphasizes floristic characteristics of vegetation such as species composition and some quantitative characters (e.g., cover value) of individual species in order to classify and characterize vegetation. The approach focuses on analysis and synthesis of the floristic composition of plant communities. A relevė or stand represents a sample of a type of vegetation, which exists in the field. Quadrats are grouped and classified according to their floristic similarities. For this, not only small numbers of dominant or co-dominant species but also a whole assemblage of the constituent species are equally weighed and examined. A group of relevės, which possess some species in common and more-or-less exclusively, is considered to be one type of vegetation.

3. METHODS OF ANALYZING VEGETATION DATA

Plant communities involve many species and environmental factors with complex relationship. Multivariate techniques are normally employed to study the complex nature of plant communities with the general objectives of summarizing large complex data sets obtained from community samples, aiding in the interpretation of the data and the generation of hypothesis about community structure and variation (Gauch, 1982; Gauch and Whittaker, 1972). Multivariate data consist of sets of attributes or scores for each of a number of variables, this number being greater than two and sometimes large (Jeffers, 1988). Recently there are a wide variety of multivariate techniques available to study the complex nature of the plant communities.

Many studies have pointed out that among the multivariate methods in studying the complex nature of plant communities; ordination and classification are the two main and basic strategies (Mueller-Dombois and Ellenberg, 1974; Whittaker, 1975). Both ordination and classification continue to contribute materially to the elucidation of the complexities within communities. Therefore the choice of the method to be used depends on the ecological question to be answered (Gauch and Whittaker, 1972; Whittaker, 1975). Moreover, the initial choice between classification and ordination rests on the convenience of the user than on preconceptions as to the continuity or discontinuity of the vegetation : if the requirement is to produce vegetation units which can be used for mapping or description, the classificatory methods are more applicable.

In classification, the individuals (i.e. the sites) are arranged in groups, the members of which have certain properties in common; in ordination, the individuals are arranged on axes, with their properties determining their positions (Lambert and Dale, 1964). Both types of methods are essentially structuring techniques, in that both are aimed at seeking a simpler structure than that of the original raw data. These two authors stressed that it cannot be too strongly emphasized that there is no a *priori* reason why the use of either method could be restricted in this way: continuous systems can be efficiently classified if classification is desired, while discontinuous (i.e. markedly heterogeneous) systems can be ordinated if ordination is thought more useful for the immediate purpose in hand. Moreover, there is in principle no reason why classification and ordination techniques should be mutually exclusive: classified units can be ordinated, and ordinated units classified. Which method to adopt at a given stage of the investigation is entirely a matter for the user, irrespective of any subjective concept of the real nature of the vegetation. Therefore, the choice between ordination and classification as a primary approach rests mainly on convenience, both in the performance of the analyses and in the use of the results.

The data analyzed are abundance or/and cover values of species recorded for a number of samples, resulting a species-by-samples matrix of observations. Multivariate analysis of such data has three general aims (Gauch, 1982). The first aim is to identify similar, redundant samples; second, to identify outliers (samples very different from all other samples); and thirdly, to elucidate relationships among samples.

Gauch (1982) categorized these multivariate analyses into three basic categories: direct gradient analyses, classification, and ordination.

3.1 Direct Gradient Analysis

According to Goff and Cottam (1967) direct gradient analysis by means of species indices and synthetic values provides a very fruitful approach to ecological investigation. Values for several species occurring together in a given stand can be combined to give a synthetic index for the stands as a whole. Direct gradient analysis is the approach from environment to floristic analysis.

The importance of direct gradient analysis in ecology by Gauch (1982) summarized as follows. Direct gradient analysis is used to study the distribution of species along recognized easily measured environmental gradients and is quite different from classification and ordination in implementation because it involves simple graphing procedures as opposed to the sophisticated mathematics and computers needed for classification and ordination. Direct gradient analysis is used to show the distribution of organisms along gradients of major environmental factors while classification and ordination begin with the analysis of community data and later use environmental data for interpretation.

3.2 Classification

Classification accepts the concept of vegetation as composed of discrete communities, which are discontinuous or markedly heterogeneous. Classification not only organizes and systemizes the findings ecology, but can also be used as a research tool because it throws into relief the similarities and differences between phenomena (Poore, 1962). But vegetation classification according to Poore (1962) is difficult due to two reasons: in the construction of the classes and in the principles to be applied to the later grouping of the classes. Furthermore, he discussed two great difficulties in the classification of plant communities and in the use of descriptions to establish correlations between vegetation and habitat. One is the frequent lack of clear-cut boundaries between communities: the other is the prevalence of complex spatial patterns in vegetation.

Classification methods aim at analyzing the ecological communities, grouping the individual stands into categories by producing final groups, which are homogenous (Whittaker, 1975). Those stands, which are closely similar with one another normally, form one class. Moreover, the properties common to a group of similar stands are used to describe that class. Classification involves the recognition of similarities between, and the grouping of, the individuals of the basic data matrix. Its main purpose according to Jeffers (1988) is to describe the relationships of objects to each other, and to simplify the relationships so that general statements can be made about classes of individuals. Greig-Smith (1983) states three objectives can be identified in the classification. Classification has one very practical function, as a basis of inventory and mapping, either as an objective in itself or as a basis of management. Classification may aim to identify 'real' entities with clear discontinuities between them, the antithesis of the concept of vegetation as a continuum. Classification may be a tool in the exploration of correlations between vegetation and environment.

The strategy of producing a classification may either divisive or agglomerative (Lambert and Dale, 1964; Greig-Smith, 1983; Digby and Kempton, 1987; Jeffers, 1988). Divisive strategy begins with the whole population of sites and divide it successively to produce a hierarchy into smaller groups, each group being examined independently for possible further subdivision as it is extracted; agglomerative begins at the bottom and combine the individual sites which are most alike building hierarchy from the bottom until all individuals are eventually united in a single population. Divisive methods thus concentrate essentially on differences, while agglomerative methods seek similarities. Divisive methods start from maximal information obtained over the whole population, while agglomerative techniques start from single units of minimal information. Divisive methods can be terminated at any convenient levels, while agglomerative methods require the whole analysis to be completed before the large-scale divisions at the top of the hierarchy can be obtained. Lambert and Dale (1964) generalized that divisive methods are to be preferred on theoretical grounds, although the actual calculations involved frequently require computing time.

Furthermore, a strategy may be monothetic, based on a single criterion at each stage, i.e. the presence or absence of a single species, polythetic, using many species as the criteria at each stage, i.e. assessment of overall similarity between stands. In principle, the divisive-monothetic classification is straightforward. The data are divided on the presence or absence of each species in turn and that division is accepted which gives the minimum residual heterogeneity, measured in some appropriate way, within the two resulting subgroups. The theoretical advantage of polythetic systems is that the classification obtained is usually more stable and, by its nature, more informative; against this, monothetic methods usually involve much less computation (Lambert and Dale, 1964). Monothetic procedures have the disadvantage that they ignore much of the information in the data.

3.3 Ordination

Study of the causal factors determining the distribution of plants and vegetation is the prime objective of ecology. The number of factors affecting plants, however, is very large and an initial problem in many investigations is to identify those factors, which are most likely to be of overriding importance in determining the occurrence of particular species and kinds of vegetation. Ordination is a means of analyzing field observations for the purpose of recognizing such factors i.e. one of the major objectives of vegetation science is to understand the environmental patterns underlying vegetation composition. Ordination thus widely used in plant ecology as a tool for examining relationships between environment and vegetation. It is used to summarize the continuous variation, which is often present in classification data, but it ignores details of the pattern and composition of undergrowth species. Ordination procedures in multivariate analysis have as their aim the arrangement of the individuals in as small a number of dimensions as possible, while retaining as much as possible of the information contained by the data (Jeffers, 1988). Mueller-Dombois and Ellenberg (1974) described ordination as a technique, which aims at description through the arrangement of samples and stands in order of similarity or environmental gradients.

The concept of ordination is based on the premise that there are no discontinuities in natural vegetation, except where there may be discontinuities in the physical environment; the process of ordination involves an attempt to place each stand of vegetation in relation to one or more axes in such a way that a statement of its position relative to such axes conveys the maximum amount of information about its composition (Anderson, 1966). If, however, the data are markedly heterogeneous, projection onto a small number of axes is likely to be rather uninformative (Greig-Smith, 1980). Thus ordination is most satisfactory when applied to sets of stands of fairly similar composition.

Ordination method was used to arrange sample sites along axes on the basis of data on species composition .The aim of ordination is to arrange the points such that the sample quadrats that are close together correspond to sites that are similar in species composition (Goodall, 1954). Figure 3 shows this (using Detrended Correspondence Analysis, DCA). The ordination axes are constrained to optimize their relation with a set of environmental variables. The ordination technique offers a framework within which pattern of species distribution can be correlated with a number of environmental factors thereby demonstrating the relationship.

In order to determine similarities or (dissimilarities) in vegetation (species presence, absence, abundance), the procedure Canonical Correspondence Analysis (CCA) was applied to the vegetation data. CCA is a multivariate indirect gradient analysis technique that searches for the major gradient in the species data irrespective of any environmental variable. CCA is contained in the computer program CANOCO version 4.5.3 (ter Braak and Smilauer 1998).

4. DESCRIPTION OF THE STUDY AREA

4.1 General Features

The study area is part of the Great Rift Valley system and is located about 200km south of Addis Ababa between latitudes of $7^0 30'$ to $7^0 40'$N and $38^0 35'$ to $38^0 45'$E and 1580m a.s.l. Abijatta Lake is part of the Abijata-Shala Lakes National Park. The park has been established in 1970 to protect the high diversity of the birdlife, particularly water birds, and the scenic beauty of the area. The Abijata-Shala Lakes National Park covers an area of around 700km^2, more than half of which consists of the Lakes Shala and Abijatta. The topography of the area is generally flat with elevation ranging about 1570m to 1780m above sea level. It is predominantly a bird sanctuary.

L. Abijata is one of the Rift Valley Lakes, which are a group of lakes sharing the same closed internal drainage. These lakes are Langano, Shalla, Ziwai and Abijata. In the late Tertiary, these Lakes basin was continuous with the Awash River drainage system in the north and with the L. Awassa and L. Abaya in the south (Mohr, 1962, 1971; Grove *et al.*, 1975). The system thus formed a single lake (Gasse and Street, 1978; Grove and Goudie, 1971). The four lakes were later separated during the Pleistocene Period (Gasse and Street, 1978) by volcanic and tectonic activities, shrinkage in water levels and by upward faulting (Mohr, 1962, 1971).

Three rivers Gogessa, Bulbula and Hora Kello feed Lake Abijata. Some literatures indicate that Gidu River flows into L. Abijata at times of high flows. The Lake has the average depth of 8.9m and it is highly alkaline varying from 9.3-10.1pH (Kassahun Wadajo, 1982; Tenalem Ayenew, 2001). According to some literatures, in the1970s and 1980s, it had an area of 19600 ha, and had plenty of fish, but, by 1995, it had shrunk dramatically and no fish-eating birds are seen at the Lake. Water is being removed from the Lake to feed a soda-ash extraction plant, and from the main feeder river, Bulbula, for irrigation. The soda-ash extraction plant on the northeast side of Lake Abijata is the largest user of the lake. Since this plant was established, the area of the lake has diminished. Tenalem Ayenew (2001) discusses that on the average, Abijata and Shala have the highest surface temperature. Lake Abijata has higher surface temperature compared to Lake Shala. This is related to its shallow depth, the thermal properties of the lake water, bottom sediments and the influence of the surrounding soda grounds. In the Lake Abijata lower temperature is related to areas where rivers Bulbula and Hora Kello enter into the lake from the north and the highest temperature distribution is related to areas in the southern and northern shallow part of the lake.

The hydrology of Lake Abijata is complex. Its water level varies irregularly over periods of several years. According to Wood *et al.* (1978) the level dropped from September 1964 until June 1967 then rose until October 1971 to about 5-6cm. It then dropped again, and had returned to its 1967 level by January 1978.This fluctuation has been related to the amount of rainfall in the catchment basins of Lakes Ziwai and Langano. Kassahun Wadajo (1982) has also observed the fluctuation of the lake during the year 1971-1981. According to his observation the level decreased from a height of 2.0m in November 1979 to near 0m (to the original) between May and September 1981. Then a rise in about 6cm in the lake level in October 1981 was observed.

Belluomini *et al*. (2000) suggested two factors which may be responsible for the progressive lowering of Lake Abijata. The first factor is climate change expressed by strong fluctuating rainfall, which in turn was the major factor controlling hydrologic budget in the region during Late Quaternary. Secondly together with this pattern of strong climate change, volcanic and tectonic activities played a major role, respectively in supplying huge amount of volcanic material to the lake and controlling size and geometry of the lacustrine basin.

The streams flowing into the lake might also affect its level. According to Reid (1961) streams often fall into the category of external factors, which shape the morphology through alternation of the shoreline and bottom. Depending upon the velocity of the stream and the substratum over which it is flowing, even a small stream may contribute sediments to a lake. Heavier particles will usually settle out near the mouth of the stream and form a delta. Lighter sediments may be carried further in the lake where they sink to the bottom. In Lake Abijata, the deposition of sediment entering through the rivers has led to a shallow area extending into the lake, and this divides the main shallow regions in the north from a deep groove in the south (Baxtrer *et al*., 1965; Baxtrer and Urban, 1970). The map of the study area with the portion of transects shown in figure 1.

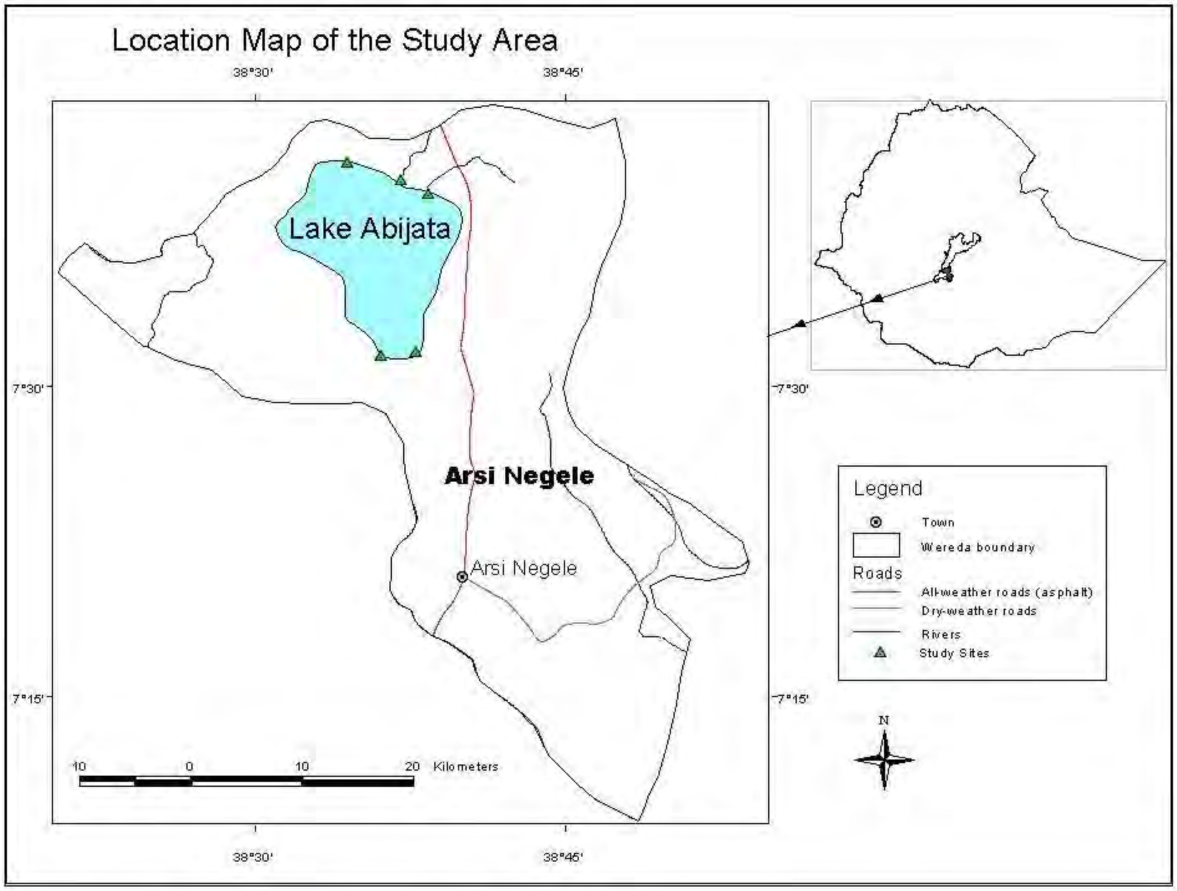

Figure 1. Map of Lake Abijata. The portions of transects are indicated by ▲

4. 2 Geology and Geomorphology

As part of the Great Rift Valley the geologic history of the study areas began from the late Mesozoic, when Africa was separated from the rest of the Gondwanaland. Geomorphic processes in the lakes Region are driven by four factors: tectonics, climate, soil nature and man, combining to shape a landscape dominated by catastrophic erosion phenomenon (Carnicelli *et al*., 2000). Tectonics were active in Holocene, with major effects. Hydrologic networks were disrupted. Holocene climate changes affected landscape stability; alternating moist and arid periods produced vegetation crises and base level fluctuations.

4.3 Soil

The physical and chemical compositions of soils are very important in determining the occurrence, growth, diversity and distribution of plant species of the area. The soil of the study area is often alluvial and very fine in nature, and is very susceptible to both wind and water erosion.

4.4 Climate

Climatic factors, rainfall and temperature are the major environmental factors that play significant role in the growth, and distribution of plants. Present climate shows a highly variable rainfall, concentrated in a few months, falling mostly in very heavy showers with intensities of 120-160 mm/h (Carnicelli *et al*., 2000). The main rains in the study area occur between July and October with the maximum in the months of July and August. The annual rainfall in this area varies between 450 and 700mm. According to data obtained from the Ethiopian Meteorological Authority its mean annual temperature varies between 19.6^0C and 25.6^0C. Both annual rainfall and temperature vary from year to year. The physiographic history of the rift creates considerable variation on the climate, which is reflected in the growing seasons. In the rift valley areas a common climatic feature is that evapotranspiration exceeds the rainfall and hence annual water deficit. Thus, the regions are part of the arid agro-climatic zones. The climatic diagram of the study area is given in Figure 2.

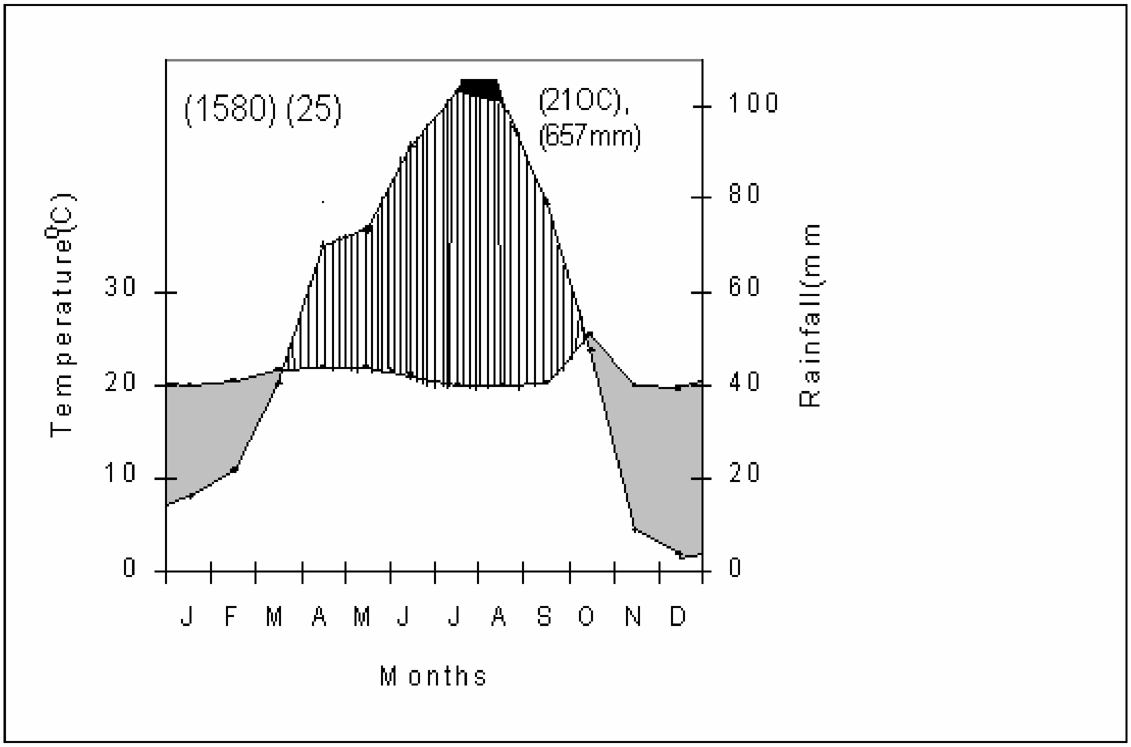

Figure 2. Climatic diagram of Abijata, 1580 m a.s.l., 25 years of observation. (After Walter, 1973).

4.5 Vegetation

The natural vegetation of the region is dominated by woodland savanna, where scattered trees and shrubs interspersed with herbaceous elements and open grasslands. In the nine broad vegetation types of Ethiopia discussed by Zerihun Woldu (1999), the Rift Valley area is categorized in *Acacia-Commiphora* (small-leaved) deciduous woodland vegetation types. The vegetation mostly consists of the *Acacia* woodland and bushland. Grass, bushes and shrubs cover the area around the Lake Abijata. The shoreline is generally sloping with the ground covered with salt-tolerant grasses, particularly *Sporobolus spicatus*. In the *Acacia* woodland, there used to be a more or less continuous canopy at 2-5m. The vegetation consists of *Acacia tortilis, A. seyal, A. senegal, A. sibieriana, and A. etbaica.* But most of the trees have now been felled and turned into charcoal or sold as a fuel wood. Much of the vegetation type has also been cleared for agriculture. This together with overgrazing has left much of the soil bare.

4.6 Land Use

The most widespread land use in the area is livestock production mixed with subsistence crop cultivation. Livestock production is the principal component of agricultural activity. The most general trend evidenced in Lake Region of Ethiopia was the increase in cultivated surfaces. Human settlement and sedentary agriculture in the Rift Floor began (Blluomini *et al*., 2000). In the Abijata Lake area, agricultural expansion appears to have taken place with little matching with soil conditions. Strong expansion is noted in areas where serious fertility and sustainability constraints exist (Carnicelli *et al*., 2000). The driving force of such unconditioned expansion is the combination of demographic pressure. The overall result of historical processes was a generalized increase in crop husbandry. The consequences of these changes include intensified use of a vulnerable land, which was accompanied by an increased rate of soil erosion and other processes of soil degradation.

The human interference in this area has been a very serious threat to the existence of the Abijatta-Shala National Park from the very beginning. The land area of the park is already heavily eroded because of constant tree cutting. People who occupy the adjacent areas continue to encroach into the park for cultivation, charcoal burning and grazing.

Around L. Abijata, there are a large number of fish eating birds. The Great White pelicans, Cormorants, African fish eagles, fish eating ducks, darters and grubs are abundant. These birds are a valuable tourist resource.

5. PROJECT OBJECTIVES

5.1 General Objectives

To identify and describe the plant communities and plant species diversity around Lake Abijata.

5.2 Specific Objectives

- To describe the vegetation and plant community types in the study area.
- To produce a species list for the area.
- To investigate the relationships between some environmental factors and plant communities.

6. MATERIALS AND METHODS

6.1 Vegetation Sampling

Reconnaissance survey of the vegetation around Lake Abijata was conducted in December 2001 to identify sampling sites. Five transects were determined randomly considering different conditions such as disturbances caused by human and livestock and accessibility to the shore of the lake. Transects are used because they are of considerable importance in the description of vegetative change along an environmental gradient, or in relation to some marked feature of topography. Field data collection has been conducted in December 2001, November 2002 and August 2003. Five transects with different lengths are: transect 1 consists 24 quadrats and its length is 120m, transect 2 consists 25 quadrats and its length is 125m, transect 3 consists 20 quadrats and its length is 100m, transect 4 consists 35 and its length is 175m and transect 5 consists 39 quadrats and its length is 195m. The five transects were laid from the shoreline to the open land. Along each transect quadrats of different sizes were laid systematically at intervals, 1m X 1m, 5mX5m and 10mX10m quadrants were laid for herbaceous, shrubby and woody species respectively to collect floristic data. A total of 143 sample units from the five transects were analyzed. Plant specimen have been collected in triplicate and identified using some identified specimens and different Floras volumes of Ethiopia and Eritrea indicated in the reference section. In each quadrat a cover value of all plants was estimated.

6.2 Environmental Data

Soil samples were taken from the depth of 0-20 cm (surface soil) from different regions (regions which seem different from each other) around the lake using a soil auger, close to the center of the sample. Metal cylinders were used to collect soil cores to determine bulk density. Bulk density values are expressed as grams per cubic centimeter. The soil was taken to the Soil Laboratory of Department of Biology, Addis Ababa University, for analyses following Juo (1978) and Sahlemedhin Sertsu and Taye Bekele (2000). Soil samples were air-dried, grounded and passed through 2mm sieve for analysis of pH, soil texture classes analysis (% sand, % silt and % clay), cation exchange capacity (CEC). The cation exchange capacity (CEC) of soils was determined by saturation with 1N sodium acetate followed by replacement of sodium on the exchange complex with 1N ammonium acetate at pH 7. Sodium levels were determined by atomic absorption spectrometry (AAS) available in the Department of Chemistry of Addis Ababa University and CEC expressed as meq/100g of soils. Soil samples have been weighted in the field and reweighed in the laboratory to determine moisture content. The pH and Electric conductivity of the soil samples were determined using pH meter and conductivity meter respectively from 1:1 soil-distilled water mixture (20g of soil in 20ml distilled water). Moisture content of the soil was determined by weighing soil samples in the field and re-weighing the samples after the samples have been oven dried in the laboratory.

6.3 Data Analysis

Vegetation data for each plant species which were originally estimated and recorded in the form of percent cover values were converted into cover/ abundance values of Braun Blanquet (1965) Scales modified by van der Maarel (1979). The relationship between environmental variables was analyzed using Pearson's product-moment correlation coefficient available in the statistical analysis systems using a computer program SPSS and CANOCO for Windows version 4.5.3 (ter Braak & Smilauer, 1998). Canonical Correspondence Analysis (CCA) and Detrended Correspondence Analysis, (DCA) ordination method were applied to the data using the computer program CANOCO to show the linear combination of the environmental variables measured and explain variation in the species along these environmental variables. Classification of the plant species into six communities was achieved by using TWINSPAN (Two Way Indicator Specie Analysis) Version 1.0 revised in 1994 by Hill.

7. RESULTS

7.1 Vegetation Classification

A total of 97 plant species from 143 quadrats were identified representing 28 families. A list of all plant species and their family is presented in Appendix 1. Out of the 28 families 40 (41.2%) are Poaceae followed by Fabaceae (19.6%) (See Figure 4).

Hierarchical classification of the plant species into different communities has been done using TWINSPAN 1994 software. The output of the TWINSPAN shows that there are about eight communities taking the cut point at level two. The major plant species that are important for the distinguishing of each community summarized using synoptic table (Table1).

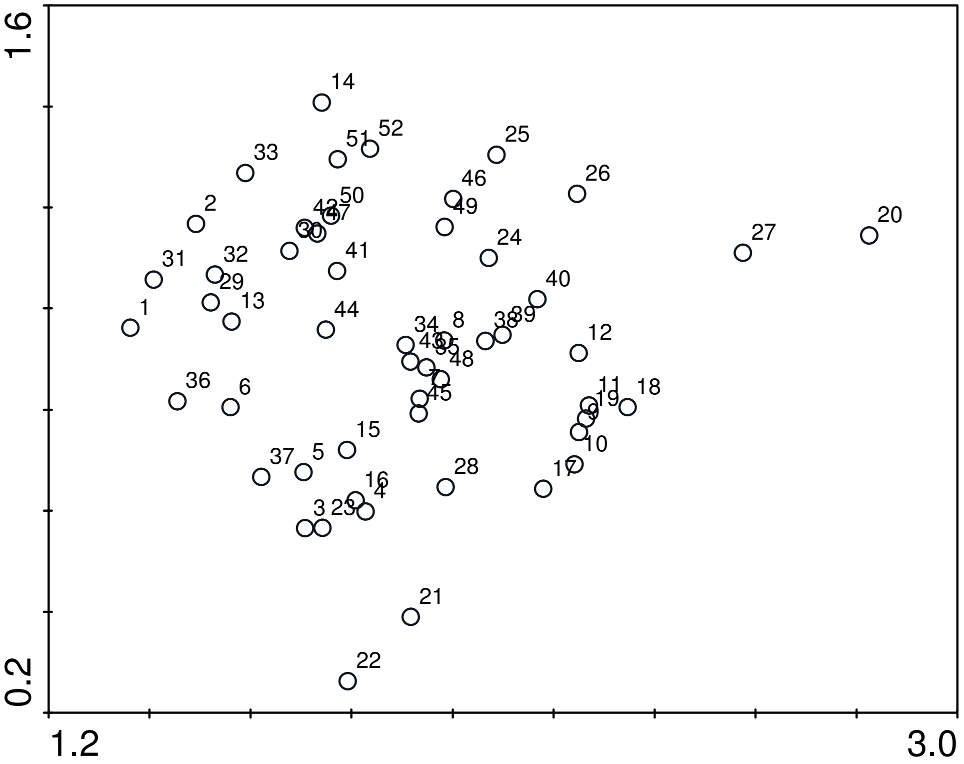

Figure 3. DCA showing scatter plot of quadrats depending on their species content

DCA used to analyses the indirect quadrat ordinations. Each point on the graph represents a vegetation sample or quadrat. The distances between the points on the graph are taken as a measure of their degree of similarity or difference. Points, which are close together, represent quadrats that are similar in species composition. This shows that the quadrats which are similar in their floristic composition along all the five transects aggregate together while those in different are dispersed.

7.1.1 Community Types of the Region around Lake Abijata

The two-way structured table of the TWINSPAN gave (Table 1) six communities. These communities are labeled with Roman numerals and named after the dominant species (See Table 1). The communities are described as follow:

Community I: *Acacia tortilis - Dichrostachys cinarea* Type

It is found at the most distant location from the lake in the woodland. The dominant woody species of the community are: *Acacia tortolis, Acacia albida*, *Dichrostachys cinerea* and *Acacia oerfota* in the tree shrub layer; *Hibiscus micranthus, Indigofera volkensii, Tagetes minuta, Medicago polymorpha, Bidens pilosa* in the shrubby layer. *Harpachne schimperi, Digitaria abyssinica* and *Commelina longifolia* are the common associated species found in the herbaceous layer. Thus, this community can be considered as a pure woody vegetation type.

Community II: *Dichyrostachys cinarea - Cynodon dactylon Type*

It is the community found nearer to the community I and somewhat far away from the region dominated mostly by grasses. It is the community which is a mixture of woody and herbaceous plant species. The dominant woody species are Acacia *tortilis*, *Dichrostachys cenarea, Acacia oerfota* and *Acacia albida* in the tree shrubby layer. The dominant shrubs and herbaceous species are: *Bidens pilosa*, *Hibiscus micranthus*, *Tagetes minuta*, *Indigofera spicata* and *Medicago polymorpha.* The dominant grass is *Cynodon dactylon.* Associated grasses with community include: *Digitaria abyssinica*, *Harpachne schimperi*, *Chloris gayana*, *Harpachne schimperi* and *Cynodon dactylon* and *Eragrostis tenuifolia.*

Community III: *Cynodon dactylon- Harpachne schimperi* Type

This is the first community dominated by grass species as one goes from the mainland (woody vegetation) toward the lakeshore. The dominant grasses are *Aristida adoensis, Harpachne schimperi, Sporobolus festivus, Eragrostis tenuifolia, Cynodon dactylon* and *Sporobolus festivus.* Though cover abundance wise they are rare, there are some shrubs associated with this community such as *Acacia oerfota* and *Indigofera volkensii*.

Community IV: *Harpachne schimperi- Eragrostis tenuifolia* Type

This community is dominated with grass species including *Harpachne schimperi, Cynodon dactylon, Sporobolus festivus, Eragrostis tenuifolia and Digitaria abyssinica.* The associated herbaceous species are *Commelina longifolia and Tagetes minuta* whereas the associated species in the shrub is *Acacia albida*.

Community V: *Sporobolus spicatus* Type

The dominant grass species are *Cynodon dactylon, Digitaria abyssinica, Chloris gayana, Digitaria ternata, Cenchrus ciliaris, Setaria pumila, Sporobolus festivus, Eragrostis tenuifolia, Eragrostia papposa, Cynodon aethiopicus and Sporobolus spicatus.* The dominant cyperus is *Cyperus laevigatus.* Dominant shrubs are *Indigofera spicata, Indigofera arrecta, Indigofera spinosa, Indigofera volkensii and Sida schimperiana* .Associated shrub species are *Acacia oerfota and Indigofera spicata.*

It is the second community as one goes from the lakeshore to the mainland (woody vegetation). The specie composition shows that this community is mainly dominated by grass species and *Indigofera* spp.

Table 1. Synoptic Table of the Abijata Vegetation with Diagnostic Species Having High Mean Cover Abundance Value and Fidelity. Dominant species in each community used to name the community are in bold.

Species	Communities					
	I	**II**	**III**	**IV**	**V**	**VI**
Acacia tortolis	**5.11**	3.00	0.14	0.68	0.00	0.00
Dichrostachys cinerea	**2.67**	**4.25**	0.16	0.00	0.00	0.00
Cynodon dactylon	0.00	**3.25**	**3.92**	3.12	3.10	4.27
Harpachne schimperi	0.44	1.50	**2.00**	**3.42**	0.00	0.00
Eragrostis tenuifolia	0.00	0.50	1.76	**2.95**	3.00	1.60
Sporobolus spicatus	0.00	0.00	0.32	0.00	**5.00**	3.07
Cyperus laevigatus	0.00	0.00	0.00	0.00	0.00	**5.67**
Acacia albida	2.56	1.38	0.16	1.11	0.00	0.00
Acacia oerfota	2.56	2.88	0.32	0.00	2.10	0.00
Hibiscus micranthus	2.11	1.50	0.43	0.21	0.00	0.00
Indigofera volkensii	1.67	0.00	0.30	0.00	0.90	0.00
Tagetes minuta	1.56	2.50	0.35	1.11	0.60	0.00
Medicago polymorpha	1.44	1.25	0.22	0.16	0.00	0.00
Bidens pilosa	1.33	2.63	0.57	0.63	0.00	0.00
Digitaria abyssinica	0.33	1.88	1.03	1.37	3.20	0.33
Commelina longifolia	0.33	0.00	0.05	1.37	0.20	0.00
Indigofera arrecta	0.22	0.00	0.41	0.00	2.40	0.00
Indigofera spicata	0.22	1.00	0.30	0.32	1.90	0.00
Digitaria ternate	0.00	0.88	0.57	0.16	2.10	0.00
Cenchrus ciliaris	0.00	0.00	0.24	0.53	1.90	0.13
Setaria pumila	0.00	0.00	0.46	0.53	2.30	0.00
Chloris gayana	0.00	1.13	0.59	0.16	3.30	0.20
Sporobolus festivus	0.00	0.00	1.24	1.37	3.10	0.20
Aristida adoensis	0.00	0.25	1.38	0.53	0.20	0.00
Indigofera spinosa	0.00	0.00	0.92	0.79	0.20	0.00
Sida schimperiana	0.00	0.00	0.49	0.74	0.40	0.00
Cynodon aethiopicus	0.00	0.00	0.97	0.63	0.00	2.53
Eragrostia papposa	0.00	0.63	0.59	0.00	0.70	1.13

Community VI: *Cyperus laevigatus* Type

This community is the nearest community to the lakeshore. It is the community without any shrubs species. The dominant species are *Cyperus laevigatus, Sporobolus spicatus, Eragrostis tenuifolia, Cynodon dactylon, Cynodon aethiopicus* and *Eragrostia papposa.* These dominant species (*Cyperus laevigatus and Sporobolus spicatus)* in this community might have high tolerance to both alkalinity and grazing. That is why they have high abundance and cover in the community.

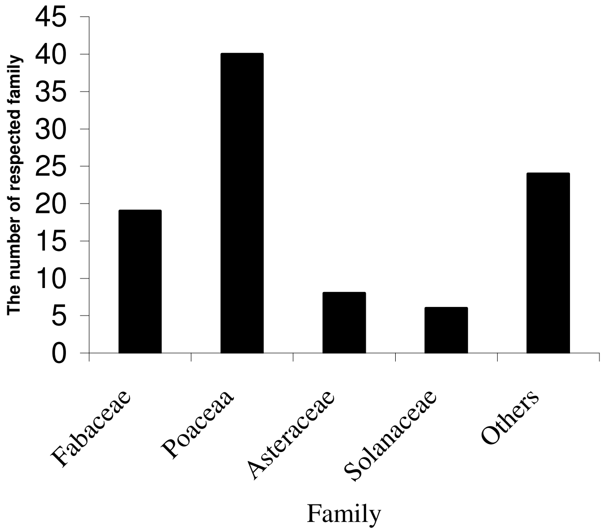

Figure 4. The bar chart showing the major families

7.2 Relationship between Environmental Variables

Changes among environmental variables differ from one place to another. There are some relationships among the environmental variables that have been studied. The relationships may be direct or indirect based on the variables taken into account. These relationships can be shown using correlation coefficient table (Table 2).

Table 2. Pearson's product correlation coefficients for correlation between environmental factors.

	CEC	EC	PH	%sand	%silt	%clay	%mois.	%BD
CEC	1.000 .							
EC	.421** .002	1.000 .						
PH	-.346* .014	.086 .553	1.000 .					
%sand	-.604** .000	-.640** .000	.118 .414	1.000 .				
%silt	.598** .000	.673** .000	-.015 .918	-.961** .000	1.000 .			
%clay	.619** .000	.539** .000	-.466** .001	-.823** .000	.708** .000	1.000 .		
%mois.	-.692** .000	-.646** .000	.332* .019	.626** .000	-.633** .000	-.654** .000	1.000 .	
%BD	-.796** .000	-.627** .000	.337* .017	.576** .000	-.584** .000	-.634** .000	.914** .000	1.000 .

**. Correlation is significant at the 0.01 level

*. Correlation is significant at the 0.05 level

7.3 Relationship between Plant Distribution in the quadrats and Soil Variables

Plant species correlation with the environmental variable was indirectly analyzed from relevės using CANOCO for Windows version 4.5.3. This shows that the sample quadrats that are close together correspond to sites that are similar in species composition and hence belong to the same community. TWINSPAN Version 1.0 also used to classify the communities which resulted in six plant communities. The distribution of the plant species along the environmental gradients has been analyzed by biplots (plant species and environmental gradients) using modified representative (three or four letters) for each species (Figure 5).

Using CANOCO the distribution of each plant species along the analyzed environmental variables is shown (Figure 5). Each point represents a species and the distances between the points are an expression of how similar the species are in their distribution across the quadrats. The greater the distance between any two points the greater the difference in the distribution of the species across all the quadrats. The figure also shows which species are related with the given environmental variables, i.e. which environmental factor determines for the distribution of the species within the quadrats.

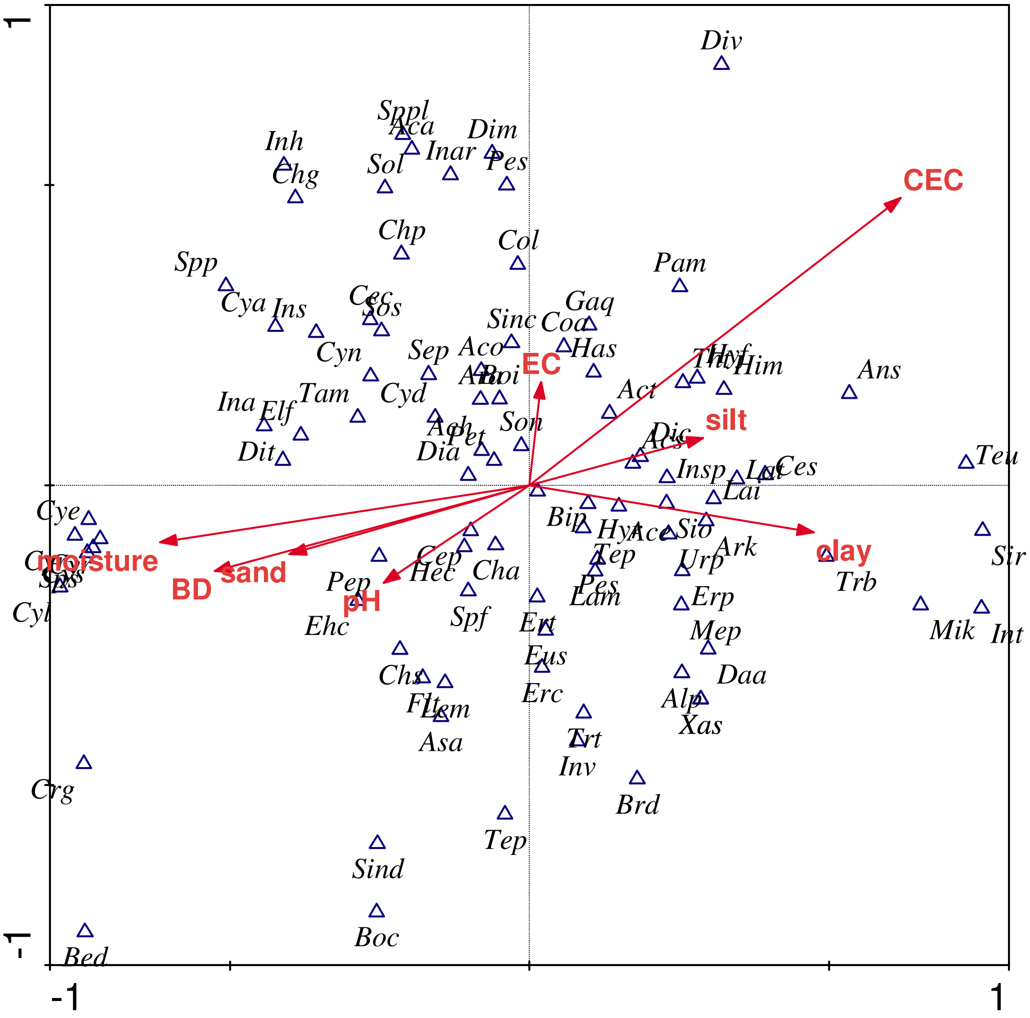

Figure 5. CCA showing the correlation among species in the quadrats and environmental variables (Δ indicates the plant species name shortened into 3 or 4 letters to avoid overcrowding indicated in appendix).

8. DISCUSSION

8.1 Relationships among the Environmental Variables

Texture is one of the soil physical properties investigated. It is an important soil characteristic because it determines water intake rates (absorption), water storage in the soil, and the amount of aeration (vital to root growth) and influences soil fertility (Donahue *et al.*, 1983). The soil in the study area is dominated by sandy soil particles.

There is a negative correlation between pH and CEC (cation exchange capacity) and clay. This is partly due to the low concentration of sodium carbonate and bicarbonate salts. These salts are constituents of soda ash (trona), which is used as the principal product for the Abijata Soda ash Extraction Enterprise (ASAE). As one moves away from the lakeshore to the mainland the soil contains more total nutrients (expressed in CEC) and total soluble salts (expressed in EC). PH affects the availability of nutrients because each nutrient has its own pH optimum level. The soil pH greatly also affects the solubility of minerals. Near the lakeshore the pH is very high so that most of the nutrients would not be available that shows less amount of CEC.

There is a strong positive correlation between CEC and clay particles. CEC measurements are commonly made as part of the overall assessment of the potential fertility of a soil. Most of the soil's CEC occurs on clays (Donahue *et al.*, 1983). That is why it is very small in areas near the lakeshore where sandy particle is the dominant compared to the areas far away from the lake. CEC, soil exchange sites, are the negative sites on the clay particles that are created due to the unsatisfied charges of broken sites at the edge minerals or internal ionic exchange. Soil particles carry a negative electrical charge, which attracts the positive charged plant nutrients, cations, which remain on the soil. Clay particles within the soil contain more negative sites per volume than sand or silt, so most of the captured cations will reside on the clay. Thus the amount of clay content affects the CEC of the soil. CEC is also the ability of the soil to hold onto nutrients and prevent them from leaching beyond the roots. The more CEC a soil has, the more likely the soil will have a higher fertility level. When combined with other measures of soil fertility, CEC is a good indicator of soil quality and productivity.

CEC also positively correlated with EC. Areas with high CEC have high EC. These areas located relatively away from the lake. This might be leaching of areas near the lake caused by temporal inundation that causes the loss of soluble salts. High soluble salts within the soil increase the EC of the soil (Russell, 1973).

The soil moisture content and bulk density (the density for a volume of soil as it exists naturally) values decrease as moved away from the lakeshore to the mainland. The high bulk density near the lake may be due to high grazing intensity, which causes the compaction of soil as the result of trampling (Gibson, 1988). Compressive forces lead to compaction. Theses forces cause soil to compress and lose pore space; the result can be a high bulk density soil. The soil near the lake has high moisture content and compressed easily.

Soil physical properties determine the availability of oxygen in soils, the mobility of water into or through soils, and the ease of root penetration. Texture is an important soil characteristic because in part, it determines water intake rates (absorption), water storage in the soil and the amount of aeration. Generally soil near the lakeshore is dominated by sand particles having fewer amounts of clay particles. Soil low in clay, but high in silt and sand, have a low CEC as seen in the result. Relatively the clay particle increases as one moves away from the lakeshore. They have high water holding capacity, slow drainage and then enhance fertility. By doing so they are good in supporting in increasing species diversity. CEC is one major component of soil fertility. The smallest particle, clay, contains an immensely significant characteristic, CEC. It is a general rule that the finer the texture of a soil the greater its fertility.

8.2 Relationship between Plant Distribution in the quadrats and Soil Variables

Patterns in distribution of plants in the study area show horizontal stratification where one region is mainly dominated by one type of plant species and the other species may be absent or dominated. This might be caused by environmental variables, of which soil is the main. Near the lakeshore the distribution in plants specie is very poor and only plants that can resist high alkalinity can survive. The soil near the lakeshore has small fertility, which is indirectly measured by amount of CEC.

CEC has a pronounced effect on soil fertility and availability of nutrients to plants. Sand and silt contain neither appreciable CEC, so the amount of clay is primarily critical in the measure of soil fertility. Near the lakeshore the soil consists relatively large amounts of sand particles which are poor in fertility and hence in supporting plant growth. Sandy soils in which aeration is exceptionally favorable have an inherent disadvantage in that the humus content remains at a permanently low level owing to the rapidity of oxidation and small amount of humus from few plant species rapidly oxidized and may not be available for the plants growth properly.

CEC is also very important for the distribution of the plant species. It directly correlated with plant distribution in the area. Those samples near the lakeshore having less amounts of CEC are very poor in species relative to those areas far away from the lake. Small CEC indicates that the soil has a small base content and also that very little of the organic material is humified (Clarke and Hannon, 1966). The more CEC a soil has, the more likely the soil will have a higher fertility level. Although the organic content has not been analyzed, it can be expected that areas near the lake are poor in it. This can be said from the viewpoint of plants in the areas.

The soil in the study area is generally characterized by high alkalinity (high pH), which might resulted in the distribution pattern of plant species in different zones. Alkaline soils are inhospitable media for most plants not only because of the high levels of salts present but also because of the low levels of available nitrogen and phosphate (Ramakrishnan and Kumar, 1976). Only plants that can resist can live in the areas (e.g. *Cyperus laevigatus).* Some research papers indicate that high alkalinity influences different activities (e.g. solubility of minerals, nitrogen fixation and toxicity of some minerals) in the soil, which in turn influence the distribution patterns of plants. Nitrification is greatly reduced in alkaline soils and probably does not occur at very high pH levels, while the solubility of phosphorus is greatly reduced at high pH. Strongly alkaline soils have lower micronutrient availability, except for molybdenum. Iron, zinc, manganese and macronutrients phosphorus may be deficient. Boron toxicity is a common feature of saline and sodic soils (Landon, 1991). The great difficulties experienced by plants growing in alkaline soils are absorbing enough iron, manganese, boron and perhaps other trace elements on the one hand, and phosphate on the other, not because roots are incapable of absorbing these nutrients from solutions at these pHs, but because the nutrients are in so insoluble form that the roots cannot bring enough of them into solution for their requirements (Russell, 1973). A pH range of approximately 6 to 7 promotes the most ready availability of plant nutrients. These conditions might be resulted in few plant species in areas where there is high alkalinity relatively.

The ability of a species to germinate and establish seedlings frequently determines its distribution in nature. Under saline conditions this phase of life cycle is especially critical. Areas where there is high alkalinity may affect seed germination. If this is so the distribution patterns will be affected. Salinity may affect germination in two ways (Choudhuri, 1968): salts in the soil condition may be sufficient to create osmotic pressure which will seriously retard if not prevent the intake of necessary water; or the constituent salts or ions may be toxic to the embryo or the seedlings.

As indicated above soil pH may affect different activities in the soil. One of these is the activity of beneficial microorganisms hence plant growth. Most common microorganisms grow best at pH 6-8, but are severely inhibited above 8.5 (Donahue *et al.*, 1983). High pH decreases bacterial activity and hence nitrification of organic matter. Certain bacteria help plants obtain nitrogen by converting atmospheric nitrogen into a form of nitrogen that plants can use. These bacteria live in root nodules of legumes and function best when the pH of the plant they live in is growing in soil within an acceptable pH range. In general soil pH affects the chemical reaction between plant roots and nutrients, the availability of nutrients in the soil for plant use and microbial activity.

Trampling is very high (due to high cattle population that feed on salty soil and lakeshore plants) near the lakeshore causing the soil to be compacted causing high bulk density and heavy grazing. Individuals who collect salty soil for commercial purpose may also cause trampling. For normal plant growth low bulk density is important. When soils are compacted, the bulk density increases and the number of larger pores reduced, which in turn reduces the capacity for gases to enter and exit the soil (Marschner, 1986). When bulky density is high the mechanical resistance to root penetration increases, so reducing the plant's ability to exploit its environment. Roots cannot decrease in diameter in order to enter pores smaller than the diameter of the root tip. Thus roots growing through compacted soil have to displace soil particles. The forces necessary for this displacement readily become limiting, and root elongation rates fall. The low bulk densities of soil must be attributed to the content of roots and organic material. There might be also a relationship between bulk density and organic matter. Since areas near the lake are not rich in organic content because of less plant cover they have high bulk density and hence allow the growth of few species.

Terrestrial grazers have dynamic effects on the species composition and diversity of the plant community. Thus grazing can be thought as a factor limiting stability through the removal of biomass. Soil differences main reinforce those due to heavy grazing. Possibly soil differences are accentuated by grazing and trampling. Grazing also affects germination success. All these factors resulted in less plant species near the lakeshore as compared to those areas far away where the factors are not strongly pronounced.

8.3 Plant Communities along Soil Variables

The way the six communities obtained from the TWINSPAN arranged along the transects as one goes from the lakeshore to the mainland or vice-versa shows certain patterns in plant distribution (horizontal stratification). This might be due to the soil variables which show differences along the transects. The community near the lakeshore (**Community VI**) is dominated mainly by *Cyperus laevigatus* and *Sporobolus spicatus.* Those plants are plants which are resistant to alkalinity. They are also not palatable by grazing animals. Though dominated by these two species there are some shrubs which are seen in and outside the quadrats, especially in the regions far apart (in 50 or 60 m).

The next community (**Community V**) taking the point of reference from the lakeshore towards the mainland is dominated mainly by the *Sporobolus spicatus Cynodon dactylon* and *Indigofera spicata.* This community is the mixture of both the shrubs and the grasses. The cover for the grasses is higher than that of the shrubs, especially the *Cynodon* species. Relative to **Community VI**, **Community V** contain large numbers of plant species. This might be due to the fact that the regions in which this community found are suitable for the growth of the plants. As already indicated in the previous discussion as one goes from the lakeshore towards the mainland the characteristics of the soil suitablity is increasing and this is very important for plant growth.

Communities IV and **III** are communities found in between those communities consisting mainly of grasses (**Communities VI** and **V**) and communities mainly consisting of shrubs trees (**Communities I** and **II**). They consist grasses and shrubs. In some areas where there are high cover of shrubs and the under story of these shrubs are not grazed, there some herbaceous plant species. Compared to the communities found in extremes along the transects these communities (**IV** and **III**) are not mainly dominated by few species. The plants found in these communities have close cover/abundance. They are the communities where the trees are started encroaching toward the previous communities (**VI** and **V**).

Communities I and **II** are mainly dominated by the trees, where their layers mainly covered by herbaceous plants. Though dominated and their cover/abundance is insignificant there are some grasses in the communities. But under the very open tree layers cover/abundance of other plants is rare or absent except the spiny shrubs. This might be due to the effect of grazing.

9. CONCLUSIONS AND RECOMMENDATIONS

Results of the present study revealed that the vegetation around Lake Abijata can be classified into six different community types, the distribution pattern of which is governed largely by pedological variables. These communities are: 1 – *Acacia tortilis* – *Dichyrostachys cinarea* type; 2 – *Dichyrostachys cinarea* – *Cynodon dactylon* type; 3 – *Cynodon dactylon* – *Harpachne schimperi* type; 4 – *Harpachne schimperi* – *Eragrostis tenuifolia* type; 5 – *Sporobolus spicatus* type; and 6 – *Cyperus laevigatus* type.

Species diversity in the study area varies dramatically across the soil gradients, including bulk density, pH, soil texture and nutrient availability as one goes from the lakeshore to the mainland. It appears that soil chemical factors such as pH, salinity, and nutrient availability determine the distribution of natural vegetation in the study area. Plant species diversity increases as one goes away to the mainland starting from the lakeshore showing direct correlation with the soil factors.

The study area is the portion of The Abijata-Shalla Lakes National Park established to protect the high diversity of the birdlife, particularly water birds, and the scenic beauty of the area. This is important for the tourist attraction and generating the economy of the country. But at the preset situation the park is highly under human pressure in different aspects including deforestation and discharging large amount of water from the lakes, which might be resulted in loss of all or part of the forests in the region and the waters of the lakes. These activities not only affect the biodiversity of the region but also affect the economy of the country which can be obtained from the tourists since the region may lose its aesthetic value. Therefore, it is important to take some action at least to minimize these problems. This can be achieved by different bodies including the government especially the part which concerned with conservation, the society of the region (community based conservation and public awareness) and the NGOs.

The study that has been made at preset is just small portion that should be made. Therefore, further study is important to investigate what other factors besides the ones studied to determine the distribution of the vegetation in the study area.

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APPENDIXES

Appendix 1. Lists of the plant species from the study site

	Species	***Family***	***Shortened form***
1	*Acacia albida Del.*	*Fabaceae*	Aca
2	*Acacia etabaica Schweinf.*	*Fabaceae*	Ace
3	*Acacia oerfota (Forsake.) Schweinf.*	*Fabaceae*	Aco
4	*Acacia seyal Del.*	*Fabaceae*	Acs
5	*Acacia tortolis (Forssk.)Hayne*	*Fabaceae*	Act
6	*Achyranthes aspera L.*	*Amaranthaceae*	Ach
7	*Alternanthera pungens Kunth*	*Amaranthaceae*	Alp
8	*Andropogon schirensis Hochst. ex A. Rich*	*Poaceae*	Ans
9	*Aristida adoensis Hochst.*	*Poaceae*	Ara
10	*Aristida kenyensis Henr.*	*Poaceae*	Ark
11	*Asparagus africanus Lam.*	*Asparagaceae*	Asa
12	*Balanites glabra Mildbr. and Schlecht.*	*Balanitaceae*	Bag
13	*Berchemia discolor (Klotzsch.) Hemsl.*	*Rhamnaceae*	Bed
14	*Bidens pilosa L.*	*Asteraceae*	Bip
15	*Boerhavia coccinea Mill.*	*Nyctaginaceae*	Boc
16	*Bothriochloa insculpta (Hochst.ex A. Rich) A. Camus*	*Poaceae*	Boi
17	*Brachiaria dicttyonuera (Fig. & De Not.) Stapf.*	*Poaceae*	Brd
18	*Cenchrus ciliaris L.*	*Poaceae*	Cec
19	*Cenchrus pennisetiformis Steud.*	*Poaceae*	Cep
20	*Cenchrus setigerus Vahl*	*Poaceae*	Ces
21	*Chenopodium ambrosioïdes L.*	*Chenopodiaceae*	Cha
22	*Chenopodium schraderianum Schult.*	*Chenopodiaceae*	Chs
23	*Chloris gayana Kunth*	*Poaceae*	Chg
24	*Chloris pycnothrix Trin.*	*Poaceae*	Chp

Appendix 1 contd.

25	*Commelina longifolia Benth.*	*Commelinaceae*	Col
26	*Cotula abyssinica Sch. Bip. ex A.Rich.*	*Compositae*	Coa
27	*Crassula granvikii Mildbr.*	*Crassulaceae*	Crg
28	*Croton dichogamus Pax*	*Fabaceae*	Crd
29	*Cynodon aethiopicus Clayton & Harlan*	*Poaceae*	Cya
30	*Cynodon dactylon (L.) Pers.*	*Poaceae*	Cyd
31	*Cynodon nlemfuensis Vanderyst*	*Poaceae*	Cyn
32	*Cyperus erectus (Schum.) Mattf. & Kük.*	*Poaceae*	Cye
33	*Cyperus laevigatus L.*	*Cyperaceae*	Cyl
34	*Cyperus rubicundus Vahl*	*Cyperaceae*	Cyr
35	*Cyperus rohlfsii Bőck.*	*Cyperaceae*	Cyr
36	*Cyperus squarrosus L.*	*Cyperaceae*	Cys
37	*Dactyloctenium aegypticum (L.) Willd.*	*Poaceae*	Daa
38	*Dichrostachys cinerea (L.) Wight and Arn.*	*Fabaceae*	Dic
39	*Digitaria abyssinica (Hochst. ex A.Rich.) Stapf*	*Poaceae*	Dia
40	*Digitaria volutina (Forsake.) Beauv.*	*Poaceae*	Div
41	*Digitaria milanjiana (Rendel) Stapf*	*Poaceae*	Dim
42	*Digitaria ternata(A.Rich.) Stapf*	*Poaceae*	Dit
43	*Ehretia cymosa Thonn.*	*Boragenaceae*	Ehc
44	*Eleusine floccifolia (Forssk.) Spreng.*	*Poaceae*	Elf
45	*Eragrostis cilianensis (All.)Vign. ex Janchen*	*Poaceae*	Erc
46	*Eragrostia papposa (Roem. & Schult.) Steud.*	*Poaceae*	Erp
47	*Eragrostis tenuifolia (A.Rich.) Steud.*	*Poaceae*	Ert
48	*Euphorbia schimperiana Scheele*	*Euporbiaceae*	Eus
49	*Flaveria trinervia (Spreng.) C. Mohr*	*Asteraceae*	Flt
50	*Galisonga quadriradiata Ruiz. & Pavon*	*Asteraceae*	Gaq

Appendix 1 contd.

51	*Harpachne schimperi Hochst.ex A.Rich.*	*Poaceae*	Has
52	*Heteropogon contortus (L.) Roem. & Schult.*	*Poaceae*	Hec
53	*Hibiscus micranthus L.f.*	*Malvaceae*	Him
54	*Hyparrhenia rufa (Nees) Stapf*	*Poaceae*	Hyr
55	*Hypoestes forskalii Vahl*	*Acanthaceae*	Hyf
56	*Indigofera arrecta Hochst. ex A. Rich.*	*Fabaceae*	Ina
57	*Indigofera articulata Gouan*	*Fabaceae*	Inar
58	*Tephrosia unifloria Pers.*	*Fabaceae*	Teu
59	*Tephrosia pumila (Lam.) Pers.*	*Fabaceae*	Tep
60	*Indigofera hochstetteri Bak.*	*Fabaceae*	Inh
61	*Indigofera spicata Forssk.*	*Fabaceae*	Ins
62	*Indigofera spinosa Forssk.*	*Fabaceae*	Insp
63	*Indigofera tinctoria L.*	*Fabaceae*	Int
64	*Indigofera volkensii Taub.*	*Fabaceae*	Inv
65	*Lantana trifolia L.*	*Verbenaceae*	Lat
66	*Launaea intybacea (Jacq.) Beauv.*	*Asteraceae*	Lai
67	*Launaea massaensis (Fresen.) Kuntze.*	*Asteraceae*	Lam
68	*Leucas mantinicensis (Jacq.) R.Br.*	*Lamiaceae*	Lem
69	*Lotus quinatus (Forssk.) Gillett*	*Fabaceae*	Loq
70	*Medicago polymorpha L.*	*Fabaceae*	Mep
71	*Microchloa kunthii Desv.*	*Poaceae*	Mik
72	*Maytenus senegalensis (Lam.) Exell*	*Celastraceae*	Mas
73	*Panicum maximum Jacq.*	*Poaceae*	Pam
74	*Pennisetum sphacelatum (Nees) Th. Dur. & Schinz*	*Poaceae*	Pes
75	*Pennisetum stramineum Peter*	*Poaceae*	Pes
76	*Pennisetum thumbergii Kunth*	*Poaceae*	Pet
77	*Perotis patens Gand.*	*Poaceae*	Pep

Appendix 1 contd.

78	*Rhamphicarpa heuglinii Hochst.*	*Scrophulariaceae*	Rhh
79	*Setaria pumila (Poir.) Reom. & Schult.*	*Poaceae*	Sep
80	*Sida schimperiana Hochst. ex A. Rich.*	*Malvaceae*	Sio
81	*Sida rhombifolia L.*	*Malvaceae*	Sir
82	*Solanum incanum L.*	*Solanaceae*	Sinc
83	*Solanum indicum L.*	*Solanaceae*	Sind
84	*Solanum lanzae f. Lebom and Stock*	*Solanaceae*	Sol
85	*Solanum nigrum L.*	*Solanaceae*	Son
86	*Solanum schimperianum Franch.*	*Solanaceae*	Sos
87	*Sporobolus festivus Hochst. ex R. Rich.*	*Poaceae*	Spf
88	*Sporobolus pellucidus Hochst.*	*Poaceae*	Sppl
89	*Sporobolus pyramidalis P. Beauv.*	*Poaceae*	Spp
90	*Sporobolus spicatus(Vahl) Kunth*	*Poaceae*	Sps
91	*Tagetes minuta L.*	*Asteraceae*	Tam
92	*Tephrosia purpurea (L.) Pers.*	*Leguminoseae*	Tep
93	*Themeda triandra Forssk.*	*Poaceae*	Tht
94	*Tragus berteronianus Schult*	*Poaceae*	Trb
95	*Tribulus terrestris L.*	*Zygophyllaceae*	Trt
96	*Urochloa panicoides P. Beauv.*	*Poaceae*	Urp
97	*Xanthium spinosum (L.)*	*Asteraceae*	Xas

DECLARATION

I, the undersigned, declare that this is my original work and has not been presented for a degree in any other university and that all recourses of the materials used for the Thesis have been dully acknowledged.

Tolcha Regassa ______________________

Name Signature

The Thesis has been submitted for examination with my approval as advisors

1. ____ ______________________

Name Signature

2. ____ ______________________

Name Signature