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PLANT COMMUNITIES AND DIVERSITY ALONG ALTITUDINAL GRADIENTS FROM LAKE ABAYA TO CHENCHA HIGLANDS

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PLANT COMMUNITIES AND DIVERSITY ALONG ALTITUDINAL GRADIENTS FROM LAKE ABAYA TO CHENCHA HIGHLANDS

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Abstract

Vegetation-environment relationships have been investigated in the study. Community transition and species diversity are affected among others by environmental heterogeneity. Multivariate numerical techniques were adopted to identify communities. The resemblance function for the identification of communities was similarity ratio, while correlation coefficient was used to identify species groups. Shannon-Wiener diversity index and Jaccard's community coefficient were computed to measure species diversity in a community and community transitions respectively. One-way analysis of Variance (ANOVA) was used to test the differentiation of communities due to environmental factors such as soil properties, slope and aspect. The results helped to identify five plant communities and seven species groups. Statistical analysis indicates that the differentiation of communities might partly be explained by the variation of soil properties and topographic features at $p<0.05$ level of significance, excepting Cation exchange capacity.

Community's grade gradually along altitudinal gradients as indicated by the high community coefficients 0.52, 0.53 and 0.16 (Table 1 and 2) in between adjacent communities. Shannon-Wiener diversity index revealed that species diversity and richness is high in communities 1, 2 and 3 at 1250-1800m altitudinal ranges. The high species diversity and richness could be due to environmental heterogeneity, which are associated with the effect of altitude. These communities are found in steep slopes and in areas of human settlement nearby where disturbance of the vegetation is observed. Therefore, conservation of these vegetation types should be given priority concern for the conservation of biodiversity in the study area.

Chapter One: Introduction

1.1 Background

Geologic history, topographic attributes of landforms and the diverse climatic conditions along altitudinal gradients favored diverse soil and vegetation development in Ethiopia. Mountain environments are very variable for plant growth depending on edaphic, climatic and elevational variations (Munishi, 1998). The topographic heterogeneity on the scale of individual plants or micro topography can create a complex mosaic of microsites (Huston, 1994; Parker and Bendix, 1996).

The geologic processes may influence the types and amounts of minerals found in the bedrock (Huston, 1994). This in turn affects the nature and types of soils that develop in a given area. Hence the nature of substrate (eg.texture) and availability of nutrients are highly related to the geologic process and partly to topography (Tamirat, 1994); thus influences the pattern of plant community and diversity (Huston 1994; Cowell, 1995; Parker and Bendix, 1996).

Topographic attributes of landforms such as aspect, topographic position and configuration, elevation and slope steepnes may dictate the availability of resources required by plants and influence environmental conditions of a particular site (Parker and Bendix, 1996). They influence the distribution and pattern of individual plants or communities indirectly by regulating micro-climatic and hydrological processes in the site (Veblen and Lorenz, 1986; Huston, 1994; Parker and Bendix, 1996).

The effect of topographic attributes of landforms is important in creating microsite conditions that differ along altitudinal gradients by redistributing resources such as water, soil nutrients and solar energy across a landscape (Huston, 1994; Parker and Bendix, 1996; Pinder III et al., 1997). For instance, slope steepness and slope aspect may influence the distribution of moisture and solar radiation and thereby create microsites.

The above factors could be some of those factors that influence for high diversity and richness of species in Ethiopia. According to World Conservation Monitoring Center (WCMC, 1992), Ethiopia has c. 6500-7000 species of higher plants of which nearly 10.5% are endemic to the country. Thus Ethiopia has got a large stock of biotic diversity. This may be partly due to the over all diversity of the habitats and ecosystems. If there are abrupt changes in mountain ecosystems in altitude, slope, moisture gradients, temperature, rainfall and drainage, diversity may change abruptly with short distances (Munishi, 1998). These abrupt changes in site conditions accompanied by changes in the characteristics of soils, microclimatic conditions and thus result in variation of distribution, structure, and composition of vegetation (Lind and Morrison, 1974; Munishi, 1998). Hence plant community transition and diversity may be highly influenced by altitudinal gradient of environmental factors and site conditions.

Though there is a transition of plant communities, certain species may dominate along altitude gradients hence vegetation zones or belts could be apparent. This aspect has been studied in Ethiopia and elsewhere in East Africa (Kibrom Tekle, 1984; Friis, 1986,1992; Lisanework Nigatu, 1987; Zerihun Woldu et al., 1989; Meihe and Meihe, 1994; Weshe, 1999). These studies indicated elevation-related continuum in floristic structure and composition. Apart from the plant community transition, elevational clines (gradual change) of species diversity and endemism become an important issue. In Ethiopia, the proportion of endemic plants strongly rise with altitude (Meihe and Meihe, 1994:30) and diversity thought to decline with altitude elsewhere (Lomolino, 2001) but with a pattern of mid-elevational peak (Brown and Lomolino, 1998; Lomolino, 2001).

The apparent transition of plant community along altitudinal gradients needs in-depth investigation at a higher resolution by considering environmental factors, which may affect community transitions. These kinds of studies were undertaken at different parts of the country (eg. Kibrom Tekle, 1984; Lisanework Nigatu, 1987) which mainly gave emphasis to forest zonations. Vegetation-environment relationships have been studied at different parts of the country by different researchers such as Tewolde Berhan (1988); Tamirat Bekele, 1994; Kebrom Tekle et al., 1997; Mengistu Gonsamo, 1998 and Tesfaye Awas et al., 2001) studied vegetation-environment relationships and issues related to conservation in Ethiopia, Central plateau of Ethiopia, Southern and eastern slopes of southern Welo, and Gambella respectively.

This study will supplement the existing information on the relationship between vegetation and environmental factors by integrating topographic attributes of landforms, edaphic conditions and floristic information.

1.2. The Objectives

The main aim of the study is to investigate altitudinal gradient of plant community transition and vegetation-environment relationships.

The specific objectives of the study are:

1. To assess the impact of environmental factors which influence the structure and composition of vegetation along altitudinal gradients in the study area.
2. To investigate the relationships between environmental gradients and species diversity and richness in the study area.
3. To provide some information for a database for future investigation and suggest conservation options, if possible, regarding the vegetation types of the study area

1.3. Hypotheses

The present study has the following hypotheses as its guidelines:

1. Variation in topographic attributes of landforms and edaphic conditions explain the variation in plant Communities along altitudinal gradients.
2. Variation in edaphic and topographic conditions influence species richness and diversity along altitudinal gradients.

1.4. Adequacy of the Chosen Approach

Environmental gradient Analysis provides an explanation to the underlying causes of the pattern and distribution of plant communities on the landscapes (Muller-Dombois and Ellenberg, 1974). Thus, an accurate assessment of the spatial variation of environmental components are essential to understand those factors that govern the distribution of plant species along certain environmental gradients (Parker, 1982; Parker and Bendix, 1996).

Two approaches are widely used by ecologists to detect patterns of community along environmental gradient. These are Ordination and Classification techniques. Hence the former would explain the underlying reason how such variations in community pattern is related to variations in environmental conditions such as altitude, moisture, and other site conditions (Digby and Kempton, 1987; Munishi, 1998). The latter presents and maps as such those communities based on the existing or apparent discontinuities. In this paper the classification technique is adopted.

Digital elevation model is used to retrieve information on topography such as altitude and slope aspect; Slope angles were measured in the field and soil samples were analyzed in the laboratory for physical and chemical properties. These data would give the necessary information regarding heterogeneity of the site.

However, these approaches may have some limitations. Environmental gradients and spatial heterogeneity are not only limited to the physical conditions such as topography, soil and moisture availability. But, plant-to-plant interaction, competition (Muller-Dombois and Ellenberg, 1974), vertical structure and complexity created by plant branches, roots and the interaction of animals within a community create spatial heterogeneity. Perhaps these are the most important factors in shaping community composition and diversity along environmental gradient (Muller- Dombois and Ellenberg, 1974; Huston, 1994).

In addition to the above factors community structure and composition and diversity is also affected by frequency and intensity of disturbance. Disturbance frequency and intensity are among the factors that affect species diversity and composition of community across spatial and temporal scales. Disturbance by fire, flooding, storms and volcanic eruptions (Huston, 1994; J. Whittaker et al., 2001) might affect diversity in local communities. For instance the frequency and intensity of fire might control the species diversity especially grasses (Zerihun Woldu and Sileshi Nemomsa, 1998) by means of reducing competitive exclusion (specifically competitive displacement) (Muller Dombois and Ellenberg, 1974; Walter, 1985; Huston, 1994; Whittaker et al., 2001). Therefore generally it is believed that frequent but intermediate disturbance might result in high diversity by inhibiting the domination of the ecosystem by few dominant species through competitive exclusion (Huston, 1994). These problems are not addressed in this study.

Chapter Two: Literature Review

2.1 Plant Communities: Discrete and Continuum concepts.

Plant communities have been defined as " a collection of plant populations found in one habitat type in one area, and integrated to a degree by competition, complementarity and dependence" (Grubb, 1987 cited in Chapman and Reiss, 1992: 168). If communities exist as a similar combinations or associations of plant species occurring repeatedly on similar habitats within a limited area as a result of competition (Walter, 1985), complementarity and dependence (Chapman and Reiss, 1992), then there should be some sort of patterns (a nonrandom, repetitive organization) that has been caused by some general casual processes (Brown and Lomolino, 1998).

As indicated by Palmer and Van Staden (1992) investigation of community patterns, such as community unit and individualistic concepts, helps one understand how plant communities and individuals may respond to environmental variables along the gradient. But what variables influence the distribution of plant species and thus the community transitions? In the above definition it has been explicitly indicated that both the environmental (habitat) factors such as climate, soil and topographic conditions, and biotic factors such as competitive ability of species, facilitative aspects such as shade tolerating vs. light phase species (Walter, 1985; Chapman and Reiss, 1992) influence the distribution of species and transition of communities. In other words, it is the spatial change of the environmental factors and the subsequent response of the individual populations in a species to the changes will influence the distribution of species and therefore transition of communities (Chapman and Reiss, 1992). Even though some authors (Walter, 1985) argue that plant species distribution ranges is limited mainly by competition than the environmental factors excepting in the case of extreme temperature and moisture, environmental factors play a significant influence on the ranges of species distribution.

In addition to the environmental and biotic factors such as competition, community organization may be influenced by temporal factors. This aspect may also include the dispersal mechanisms and subsequent accumulation of species in a site (Jacquemyn et al., 2001) and the developmental stage of vegetation or succession, which is given much emphasis by Community unit hypothesis. So that composition (or diversity) and structure of a given community changes as time increases.

There has long been a debate regarding community structure in the past. One school of thought considers communities as discrete units that can be identified and classified. This school, Clementesian School, understands communities as superorganisms that have its own life and structure as well as its own temporal and spatial limits (Chapman and Reiss, 1992; Brown and Lomolino, 1998). The temporal component is referred to as the developmental stages of the communities (succession) while the spatial limits are due to the response of species to environmental gradients (Brown and Lomolino, 1998). In contrast to this, others (Whittaker, 1975) argue that plant communities change gradually along complex environmental gradients (Collins et al., 1993; Brown and Lomolino, 1998) so that no distinct associations of species can be identified. This is the Continuum community concept. However recently Collins, Glenn and Roberts (1993) have proposed a “hierarchical continuum” concept of the community patterns. This model was based on the assumption that the distribution of species at a regional scale assumes polymodal curve rather than the normal distribution curve of the continuum concept. In the following paragraphs we shall discuss each of them in brief.

2.1.1.The discrete community concept:

The discrete community concept predicts that the distribution of species along certain gradients (regulator or complex gradients), groups of species or communities would replace one another (Shipley and Keddy, 1987). "Within each grouping most species have similar distributions and the end of one group coincides with the beginning of another"(Shipley and Keddy, 1987, p.48). In this case, however, species with wider distribution ranges are avoided and distinction of the community is on the basis of character or indicator species (Barbour et al., 1987).

For discrete communities to exist it must show discontinuities over the continuous environmental template (Roberts 1987). Discontinuities in communities could occur if few potential dominant species may control the environment and avoid others by competitive exclusion (Roberts, 1987) and subsequent modification of the environment by the vegetation. The discontinuity in community organization would also occur if the environmental variables change abruptly as in the case of cliffs, lake shore and so on (Chapman and Reiss, 1992, Brown and Lomolino, 1998).

2.1.2.The Continuum Community Concept

The continuum concept contends that plant community's change (in their composition) gradually along the complex environmental gradient and hence identification of distinct community association is not possible (Collins et al., 1993). The distribution centers (peaks or abundance) and species range boundaries are widely scattered so that no groups of species would aggregate to form a distinct community unit (Barbour et al., 1987). Rather each species has its own physiological tolerance limit to environmental variables and the environmental variables would also fluctuate and vary across spatial scales (gradients).

For the continuum to exist the change should be gradual; and this type of community composition change is encouraged by the presence of 'many potential dominants' and the environmental change induced by the vegetation does also change continually (Roberts, 1987). For instance shade tolerant species may dominate when light is becoming scarce resource (Walter, 1985) or the change of pH of a soil that may regulate species growth through time (Roberts, 1987). Therefore the distribution and response of species along continuously changing environment is a chance factor (Barbour et al., 1987) and individual species physiological response to environments is independent of one another (Barbour et al., 1987; Shipley and Keddy, 1987).

Many ecologists have attempted to test the continuum community hypothesis with empirical data set (Austin, 1987; Shipley and Keddy, 1987). The distribution assumption of normal curve along environmental gradient is not consistent and universal pattern as the continuum community concept suggests (Collins et al., 1993) rather more skewed form of distribution is expected (Austin, 1987, Shipley and Keddy, 1987). Still others questioned the universal validity of the continuum concept to explain the species response to environment. On the other hand Roberts (1987) argued that both community unit and continuum concepts give greater emphasis to environmental factors and little attention was given to the modification effect of the vegetation and their subsequent influence of the community patterns. Shipley and Keddy

(1987) have also reported that the dichotomy of hypothesis regarding community patterns, community unit and continuum, does not exhaust the existing natural patterns hence a multiple working hypothesis must be developed.

In line with the above arguments Collins et al (1993) have tried to develop a hierarchical continuum concept. This concept takes into account the dynamic nature of vegetation as suggested by Roberts (1987) and the environmental factor variations along certain environmental gradient. In regard to the dynamic nature of vegetation, 'species will change their distribution and abundance patterns along the gradient in response to environmental fluctuations (Collins et al., 1993, P.54). Environmental resources are heterogeneous and show some sort of patches hence resulted in the fragmentation of these resources and distribution and abundance of species would vary accordingly. Therefore in response of these things the hierarchical continuum concept assumes that some species are distributed widely across the sample region while others have localized distribution and still others have much restricted distribution (rare species). Species with wider ranges of distribution and much restricted ranges (rare species) were not used by association analysis for community classification (discrete community concept). While, in the case of the continuum concept, the normal distribution curve is not a universal case since resource template is not always continuous but rather fragmentation is actually observed (Collins et al., 1993; Huston, 1994). In addition to these, the dynamic aspect of vegetation in order to modify the environment has its own influence on the organization of the community (this is what Clements called vegetation reaction). Thus, the distribution of species and patterns of abundance assumes a hierarchical structure where species with wider, intermediate and restricted distribution ranges shows some sort of hierarchies rather than a continuum or discrete alone.

In summary community pattern concepts or hypotheses discussed above provide us with insights into how plant species respond to the environmental variables along complex gradients (Palmer and Van Staden, 1992). There existed a debate as to the acceptance of the hypotheses (discrete or continuum) since empirical evidences support each of them (Collins et al., 1993). As indicated by Shipley and Keddy (1987) the dichotomy should be avoided since both of the hypotheses do not exhaust the natural community patterns but they are not competing rather complementary as well as dealing with a special case of dynamical system (Roberts, 1987, p. 31). The hierarchical continuum concept of Collins et al. (1993) can be viewed as an attempt to incorporate both hypotheses and the pattern of community organization may take hierarchical structure.

2.2. Species Diversity

Species diversity exists at different spatial scales. The most conspicuous patterns of species diversity at larger spatial scales are latitudinal diversity gradients and island diversity gradients (MacArthur, 1969; Brown and Lomolino, 1998). A number of factors or hypotheses exit to explain species diversity along latitude. The most important ones are Rapaport's rule (geographical range size), Climatic stability, environmental heterogeneity, competitions, history and water based energy dynamics are few to mention with (O'Brien, 1998; Whittaker, 2001). While in the case of island diversity gradients, remote or Small Islands may have fewer species than larger islands, which is closer to the main lands (MacArthur, 1969; Whittaker et al., 2001). The possible explanations for the island pattern of species diversity are based on the equilibrium between immigration and extinction (MacArthur, 1969; Brown and Lomolino, 1998; Lomolino and Weiser, 2001). Immigration and extinction are functions of distance and area.

Altitudinal diversity gradient is also an obvious form of diversity patterns (Brown and Lomolino, 1998) since altitudes experience double gradients of temperature and rainfall besides its isolation from the surrounding area. Species richness shows a general pattern of intermediate altitude peak (Whittaker, 1969; Brown and Lomolino, 1998). This is mainly due to the double gradient of temperature and precipitation. Therefore it is two types of gradients that act one against the other and produce a favorable environment at intermediate level of altitude.

On the fairly smaller spatial scales Alpha diversity, Beta diversity and Gamma diversity (Huston, 1994) are observed. The alpha diversity as indicated by Whittaker (1969) is the level of diversity within a habitat or individual communities. The within habitat diversity may be the result of the inherent quality of the community itself, i.e., the characteristics of a particular species such as dominants in order to modify environments, environmental characteristics and the time over which the species evolved to differentiate ecological niches among themselves (Whittaker, 1969). In regard to beta diversity (between habitat diversity), it is defined as 'relative extent of differentiation of communities along topographic gradients' (Whittaker, 1969, p.283). While gamma diversity refers to the geographical or landscape diversity (Huston, 1994; Whittaker et al., 2001). It is the result of alpha and beta diversity. However, as indicated by some authors, the distinction among alpha, beta and gamma diversity is vague (MacArthur, 1969; Whittaker et al., 2001). Hence, Whittaker et al. (2001) prefer to use local, landscape and macro-scale instead of alpha, beta and gamma diversity respectively.

Species diversity may take any of the two forms: biogeographic diversity and ecological diversity (Whittaker et al., 2001, p.454). Biogeographic diversity is based on taxonomic distinctness or endemism while ecological diversity refers to inventory diversity (richness) or the number of species in a sample area (Huston, 1994; Whittaker et al., 2001). Thus biogographical diversity may be caused by the evolutionary factors such as geographical isolations (Whittaker et al., 2001), which might cause genetic separation and contribute to geographical diversity (Huston, 1994). While ecological diversity may result from the contemporary ecological processes and controls (Whittaker et al., 2001) such as competition, water based energy dynamics, productivity and other ecological processes (Huston, 1994).

This paper discusses inventory diversity or species richness hence the casual factors are those that are contemporary ecological processes and controls. This does not however imply that evolutionary and historical factors do not contribute to species richness at local and landscape scale (Whittaker et al., 2001) since local immigration and extinction affects local (alpha) diversity patterns (Jacquemyn et al., 2001). A number of factors can be accounted for species richness or diversity along environmental gradients such as altitude. The list may include energy based water dynamics, spatial heterogeneity, disturbance and competition can be taken as some of the major factors.

With increasing altitude ambient temperature decreases hence altitude and energy variables are negatively correlated. These energy relationships determine the subsequent biological activities and thereby influence species diversity (O'Brien, 1998; Whittaker et al., 2001). Spatial heterogeneity is also another factor, which may influence species diversity. The heterogeneity of the environment may include variation in the characteristics of soils such as nutrients, soil moisture and texture. Soil characteristics would in turn be influenced by spatial variation of topographic conditions such as altitude and slope (Huston, 1994). Therefore, greater environmental heterogeneity would mean more niche spaces and hence more diversity of species (Cowling et al., 1998; Bell et al., 2000).

Disturbance frequency and intensity are among the factors that affect species diversity across spatial and temporal scales. Disturbance by fire, flooding, storms and volcanic eruptions (Huston, 1994; J. Whittaker et al., 2001) might affect diversity in local communities. For instance the frequency and intensity of fire might control the species diversity especially grasses (Zerihun Woldu and Sileshi Nemomsa, 1998) by means of reducing competitive exclusion (specifically competitive displacement) (Muller Dombois and Ellenberg, 1974; Walter, 1985; Huston, 1994; Whittaker et al., 2001). Therefore generally it is believed that frequent but intermediate disturbance might result in high diversity by inhibiting the domination of the ecosystem by few dominant species through competitive exclusion (Huston, 1994).

On the other hand competition as a biological interaction influences species diversity (Whittaker et al., 2001). Interspecific competition determines how many species should exist together by adjusting themselves to the environmental conditions while intraspecific competition helps a given species population maintain itself there since weaker ones are eliminated from the group (Walter, 1985).

2.3. Topographic Attributes of Landforms and Vegetation Patterns

Vegetation patterns are highly affected by geomorphic influences either through landform positions or process that dictates the availability of materials such as water and nutrient (Parker and Bendix, 1996).

Topographic attributes of landforms include aspect, topographic position and configuration, slope and elevation. These are the main topographic attributes of landform and they influence the pattern of vegetation in the landscape indirectly (Parker and Bendix, 1996). For instance, aspect is one of the factors that influence the availability of moisture or level of temperature (Barbour et al., 1987). It influences the solar radiation recipient and variations of such energy on different parts of the mountains. Thus result in variation of microclimatic conditions and soil development that in turn affects the richness of species in different exposure of a single mountain. Uhlig (1988) has observed the difference in vegetation types between the southwest and northeast slopes on the Bale Mountain. The southwest receives much moisture as a result of the on-shore Guinea monsoon winds from the Atlantic oceans. However, the northeastern slopes do not get much moisture as a result of off-shore northeastern trade winds (Daniel Gamachu, 1977).

Topographic position and configuration is another important attribute of topography that influences the distribution of essential plant nutrients and rainfall (Parker, 1982; Parker and Bendix, 1996; Pinder III et al., 1997). Even though the first order explanation for woody species richness is mainly accounted to climate based energy dynamics (O'Brien, 1998), the redistribution of water after rain varies accordingly with the variation in slope position and configuration. For instance, valley bottoms and ridge tops do not receive equal amounts of moisture since valley bottoms collect moisture than ridge tops such variation in moisture in the landscape influences vegetation patterns (Frederiksen and Lawesson, 1992). In this regard Pinder III et al. (1997) indicate that slope position and steepness affect the relative abundance of herbaceous species, where valley bottoms have relatively abundant herbaceous species than ridge tops in Lassen Volcanic National Parks (USA).

Similarly slope configuration such as concave and convex slopes influences the redistribution of moisture. Concave slopes collect moisture while convex slopes disperse it and hence influences species composition and structure of vegetation (Pinder III et al., 1997). On the other hand the distribution of mineral nutrients may vary accordingly with in the landscape as 'through flow' and surface movement bring materials to the lower slope position and to the valley bottom and concave slope hence nutrients are presumed to be higher in this areas (Belay Tegene, 1997).

The effect of altitude in the distribution of vegetation has been discussed in brief in the previous sections. In Ethiopia as discussed by Zerihun Woldu et al. (1989) altitude becomes an important factor in controlling the zonation of forests, in the southeastern Ethiopia. But its effect as indicated earlier is very complex since most of the factors such as temperature, precipitation and topographic aspect and other landform parameters are indirectly controlled by altitude. For instance, steep slopes experience faster movement of water and materials hence resources available for plants in such slopes may be scanty.

Geomorphic processes may also influence the distribution and pattern of vegetation in a given landscape (Parker and Bendix, 1996). The movement of sediments across the landscape may facilitate the movement of seeds and affect germination apart from its direct impact on the physical and chemical properties of soils (Parker and Bendix, 1996).

2.4. Zonation of Vegetation in East African Mountains.

A distinct pattern of vegetation zonation is one of the conspicuous conditions of mountains in East Africa (Wesche, 1999). A number of studies made in E. African Mountains (Lind and Morrison, 1974; Wesche, 1999) including Ethiopia observed patterns of zonal distribution of vegetation (Kibrom 1984; Friis, 1986; Uhlig, 1988; Meihe and Meihe, 1994). Most of these studies and others indicate that distinct plant community types (or zones) can be observed due to the effect of altitude (Zerihun Woldu et al., 1989) and its complex relationships to temperature and moisture, soil characteristics and aspect (Uhlig, 1988; Friis, 1992; Weshe, 1999). Thus, the distribution of a given plant community and species boundary vary accordingly with the location of the mountains in terms of exposure, edaphic conditions and other topographic factors (Uhlig, 1988).

In this chapter, attempt has been made to discuss plant community patterns and diversity and the underlying causes for such patterns. As has been indicated both physical and biological factors control plant community organizations and diversity. There are a number of factors which may influence patterns of species diversity in terrestrial ecosystems such as species area relationships, energy based water dynamics, environmental heterogeneity, disturbance etc, have profound influence in affecting species diversity over the landscape. The above factors would change along altitudinal gradients and hence patterns of species diversity could be observed with increasing altitude. In addition to these the structure and composition of vegetation is highly influenced by topographic attributes of landforms and related geomorphic processes.

Chapter Three: Materials and Methods

3.1 The Study Area

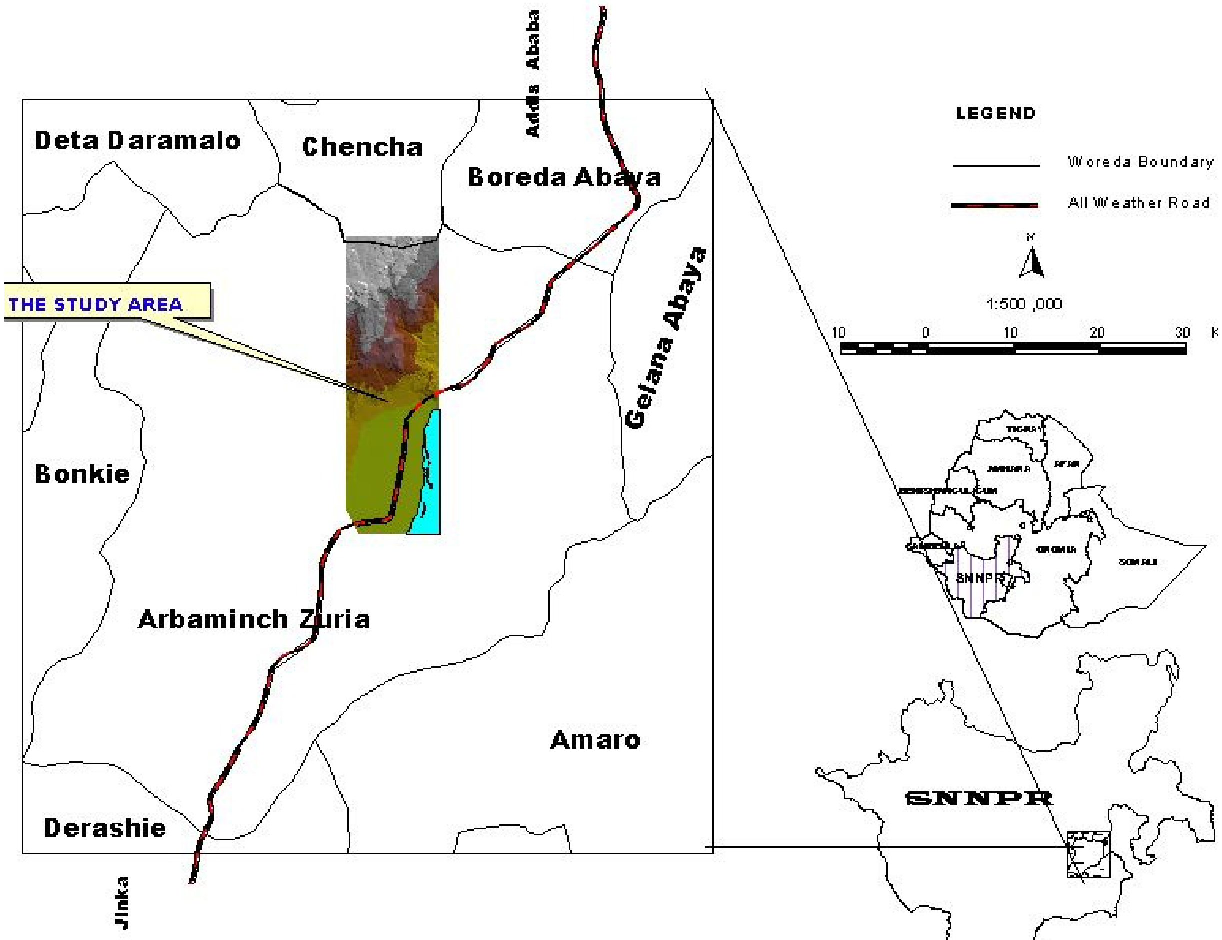
3.1.1 Location and Physiography

The study area is located in between 6°05´N to 6° 12´N and 37°33´E to 37°39´E. It is located along the western escarpment of the southern part of the Rift Valley in the Southern Nations, Nationalities and Peoples Region (Map 1). Elevation generally decreases to South and Southeast of Chencha (2718m) to 1177m at the coast of L.Abaya. The topography is rugged and ranges from steep slope at the escarpment of the Rift Valley to nearly flat surface around the coastal strip of L. Abaya (Map 2). The Drainage pattern follows the general topographic orientation so that small streams rising from Chencha highlands drain to L. Abaya. Among these Kulfo, Hare, Baso and other smaller intermittent streams drain the area (see Map 2).

3.1.2 Geology and Soils

The Geology of the lower part of the study area is of recent or quaternary volcano which serves as a substrate for the dry afromontane vegetation (Friis, 1992). Volcanic tuffs and effusive basic rocks on the surface as a result of volcanic ash are common in the lower course of Hare River (Vukasinovic, 1969).

Lake Abaya and Chamo occupy the lower altitudes in the floor at an average altitude of less than 1200m. These lakes are found in less intensely faulted rift valley floors (Mohr, 1971). Lake Abaya and Chamo were enlarged and united to form a single lake in the



Map 1: LOCATION MAP OF THE STUDY AREA

Source: Addis Ababa University Department of Geography ,1990

pluvial period. They were later, nevertheless, separated probably as a result of inter-pluvial climatic change or the down cutting and change of water level as it is the case in the central Rift Valley lakes (Zerihun Woldu and Mesfin Taddesse, 1990). As a result of the climatic fluctuations or so in the Pleistocene, extensive areas have been left out as lakes shrank in their size hence lacustrine deposits are commonly observed in the lakeshores of Abaya (Mohr, 1971). On the other hand the highlands of Chencha, basalts form the greater part of the trap series and more silicic lavas occur lying above the basalt (Mohr, 1971).

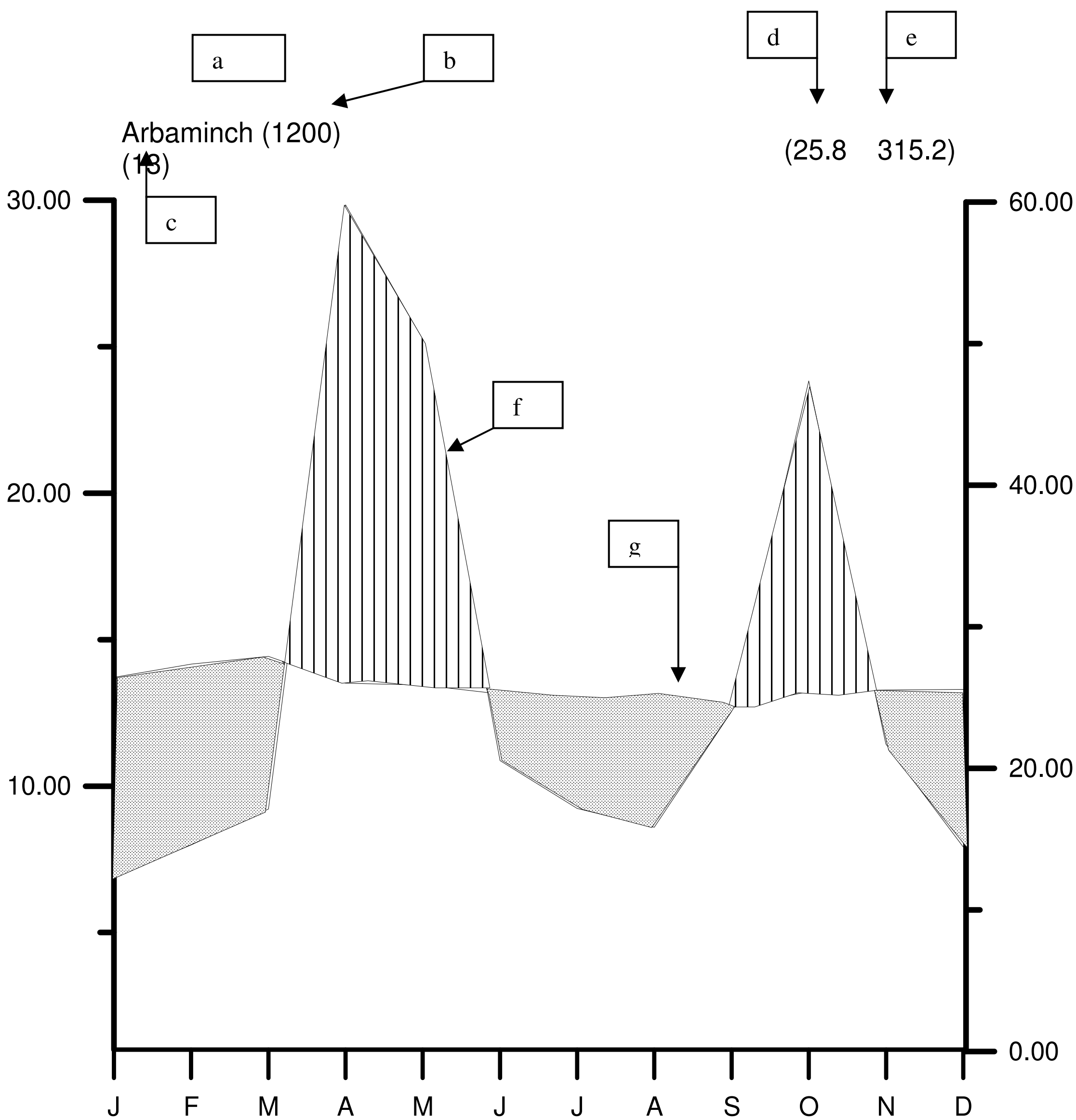
The soils along the floor of the rift valley and L.Abaya are alluvial of Hare stream (Vukasinovic, 1969), and colluvial materials and lacustrine deposits of the Pleistocene are common when Lake Abaya retreated (Mohr, 1971). Therefore, the soils of the area around the floor and L. Abaya can be categorized as Fluvisols of the FAO/UNESCO revised legend (1990). Fisseha Itana (1992) has indicated the presence of Andosols in Arbaminch area. The escarpment and highland part of Chencha may have different kinds of soils depending on the variation in topography, climate and the time involved in soil formation.

3.1.3 Climate and vegetation

Climate

The climate of the study area is semiarid climatic type (Fig.1; Walter, 1985). It receives bimodal type of rainfall distribution (Fig 1). The two wet seasons are interrupted by two dry seasons in the area; the two wet seasons lie between March/April-May and September-November. The big rain begins in March-May and small rain during September to November (Fig 1). Temperature is controlled by altitude hence it is higher in Arbaminch, mean annual temperature is about 26°c to low mean annual temperature at Chencha highlands. Based on modified köppen classification the study area lies on the Tropical rainy climate (Tropical climate II around L.Abaya and Tropical climate III on the escarpment and Chencha highlands). The rainfall conditions range from 680-2000mm in Tropical climate II to 1200-2800 mm in tropical climate III (EMA, 1988; TGE/EPA, 992).

Fig 1 The Climadiagram for Arbaminch (Mean Temperature in ºC and Rainfall in mm for the years (1987-2000) After Walter, 1985



Source: National Meteorological Services Agency

Key: Ordinate axes indicate mean monthly temperature on the left and mean monthly rainfall on the right. The temperature rainfall relationship is 1:2 ratios for plotting. Abscissa axis indicates months. a. Station, b. Altitude of the Meteorological Station, C. Years of observation, d. Mean Monthly Temperature, e. Mean Annual Rainfall of the Station, f. Rainfall curve, g. Temperature Curve.

Vegetation

Many authors have attempted to classify the vegetation of Ethiopia to date. However, most of them have employed physiognomic criteria to make a classification (Friis, 1992, Tesfay Awas et al., 2001). For instance, Pichi Sermolli (1957) and Greenway (1973) have used physiognomic formations. Pichi-Sermolli categorized the vegetation in 24 physiognomic formations out of which 22 were found in Ethiopia (Zerihun Woldu, 1999). White (1983), however, has classified the vegetation of east Africa on the basis of endemism (Zerihun Woldu, 1999). He categorized the vegetation in three groups such as Sudanian Regional Center of Endemism, Somalia-Massai Regional Center of Endemism and Afromontane Archipelago-like Regional Center of Endemism (Zerihun Woldu, 1999). Recently Friis (1992) has also classified the vegetation of North East Tropical Africa on the basis of physiognomic information and Zerihun Woldu extensively reviewed this and other earlier works such as Pichi Sermolli's (1957) and broadly classified the vegetation of Ethiopia in nine broad categories (Zerihun Woldu, 1999)

According to White's classification the present study area is found in the Somalia-Masai Regional Center of Endemism. But based on the broad categorization of Zerihun Woldu (1999) and EPA/TGE (1992), the vegetation in the study area is mainly Acacia-Commiphora and evergreen scrub (TGE/EPA, 1992; Zerihun Woldu, 1999). The former group includes species such as *Acacia tortilis*, *Balanites aegyptica*, *Acalypha fruticosa*, *Barleria eranthemiodes*, *Combretum spp*, *Terminalia spp*, etc, while the latter includes species such as *Dodonaea angustifolia*, *Acokanthra schimperi*, *Ximenia americana, Clutia abyssinica, Maytenus arbutifolia Rhus natalensis,* etc. However with increasing altitude one would find elements of Combretum-terminalia woodland, and forest vegetation, which forms patches as a remnant of intensive agricultural practices in the highlands of Chencha.

3.1.4 Population and Land use

According to the 1984 Census, the population of Arbaminch Zuria woreda (sub-district) had 94,426 (CSA, 1987). After a decade the population of the woreda grew considerably and reached 153,550. The population of Chencha based on 1994 Population and Housing Census was 88, 040 (CSA, 1996). The total population of the two woredas is 241, 590, which represents 9.27% of the total population of Semen Omo Zone (district). Out of this 78.5% of Arbaminch Zuria and 94% of Chencha Woreda are rural populations (CSA, 1996).

Aerial photographs and field observation (2 Nov.-5 Dec.2001) indicates that the main types of land uses in the study area are subsistence agriculture in the highlands of Chencha, subsistence and small and large scale commercial farming in the floor of the rift valley around Arbaminch town.

The increase in population size, urban development and expansion of commercial and subsistence farming has exerted considerable influence for the degradation of woodland vegetation in the rift valley region of Ethiopia (Zerihun Woldu and Mesfin Taddesse, 1990).

The study area is no different from this wave of influence as a considerable part of it lies in the Rift Valley floor and the escarpment where many development processes are on the way.

3.2. Data Collection

3.2.1 Vegetation Sampling

Vegetation data were collected by using a relevé. A relevé is defined as an attempt to describe a plant community in space and time (Andreucci et al., 2000). A belt transect method is used to determine relevés along altitudinal gradient which range from L.Abaya to Chencha highlands. The data were collected during 12 Nov. to 5 Dec. 2001; this period is selected because maximum diversity is expected, as it is the end of a big rain in the area (Daniel Gamachu, 1977). Two transects have been laid down to the right and left along the road (Arbaminch—Chencha road) for ease of access. Each transect was laid out 50 meter to the left and right of the road in order to avoid effects of the road.

The systematic sampling technique was used. Thus two transects ran for about 30 km from 1180m-2250m along altitudinal gradient hence in every 25m vertical distance (ascent), 48 relevés of 20m x 20m were laid and floristic information collected. While the remaining 2 relevés at the lakeshore had a size of 40m x 40m due to the structure of vegetation following the standard method mentioned in Muller-Dombois and Ellenberg (1974). Therefore a total of 50 relevés were sampled. The percent Cover values are visually estimated in the field and later converted into 1-9 modified Braun Blanquet scale (Van der Maarel, 1979), height class and density have been collected using Braun Blanquet method of relevé (Muller-Dombois and Ellenberg, 1974). Plant specimens collected were pressed in the field and brought for identification in the National Herbarium (AAU). Nomenclature follows Hedberg and Edwards (1989 and 1995), Edwards et al., (1995 and 1997).

3.2.2 Environmental Data

From each relevé a composite soil samples have been taken from the depth of 0-30cm. The soil samples were collected from each corner and center of the relevé. Thus from each relevé five auger samples were obtained and a composite sample was made.

The soil samples were analyzed in the EARO (Ethiopian Agricultural Research Organization) soil laboratory at Debre Zeit. The samples were air dried, sieved with a mesh size of 2mm. Then, the samples were analyzed for pH, texture, total nitrogen, and available phosphorous, organic matter and Cation Exchange Capacity.

pH was measured using a pH meter at 1:2.5 distilled water to soil suspension. Texture was determined on the basis of Bouycous Hydrometer method while total Nitrogen is determined by using Kjeldhal method. Walkley and Black method of titration was used to determine organic matter content. Cation exchange capacity and available phosphorous were determined on the basis of NH_4Oac method (Ammonium acetate method) and Olson method respectively.

Topographic map (1:50,000) is digitized by using ARCVIEW 3.2/GIS. The digitized map is rectified for its coordinates. Then the data were imported from ARCVIEW 3.2 to ArcInfo and Mapinfo/GIS software for data conversion process and then Arcview 3.2/ GIS Software was used to produce a DEM (Digital Elevation Model). As DEM is geo-referenced, it would help generate topographic information such as altitude and aspect.

UTM (Universal Transverse Mercator) horizontal position readings were recorded for each relevé by using GARMIN GPS 3 in the field and later these UTM coordinates entered in the geo-referenced map so that the position of each relevé is determined. So long as the positions are determined in the map, the altitude of each relevé can easily be retrieved from the map by interpolation. In addition to altitude and aspect, slope steepness was measured by using a Clinometer and surface stone cover was measured in the field using FAO/UNESCO (1990) guidelines for soil profile description i.e. 100 cm x 100 cm ….is laid down randomly in the relevè and measurement was taken as how many percent is occupied by stones). Note that in the measurement of stone cover big boulders are also considered in the field.

3.3 Data Analysis

3.3.1 Vegetation Classification and Definition of Communities

The program SYNTAX 2000 for windows version is used to classify the vegetation data. A hierarchical clustering technique is employed to classify vegetation data on the basis of group average linkage. Group average linkage is a hierarchical polythetic agglomerative classification technique (Digby and Kempton, 1987). Communities were identified based on groupings of relevés, and seven species groups were produced. "Plant communities whose relevés are considered similar enough are grouped into the same community" (Andreucci et al., 2000). The resemblance function used for relevé grouping was a similarity ratio while species groups were identified by Coefficient of correlation

3.3.2 Statistical Analysis

The mean values of environmental variables for each community were computed and one-way analysis of variance (ANOVA) was used to determine if there is a significant variance among environmental factors and the communities. The program SPSS 10 for window version was employed to carry out the ANOVA. Statistical measurement regarding species richness and diversity was carried out by Shannon-wiener (1949) diversity index. The formal for Shannon-Wiener diversity index is -sum pi ln pi. Where pi is the proportional cover of a species to the total species in a community.

Jaccards coefficient of similarity was calculated to see the species composition turnover. Jaccard's coefficient of similarity is computed to see whether communities and species composition grades gradually or in discontinuity. The formula for Jaccard's coefficient of similarity is SJ= a/(a+b+c). Where 'a' is the number of species recorded from both altitudinal ranges/ communities in this case and 'b' and 'c' are the number of species confined to one or the other of the two ranges or communities (Friis, 1992, p.62-63).

Values for aspect was codified following Zerihun Woldu et al., 1989 where N=0, NE=1, E=2, SE=3, S=4, SW=3.3, W=2.5, NW=1.3, Ridge top=4 (Zerihun Woldu et al., 1989) before analysis. The percentage slopes of each relevés were measured in the field by using a

Clinometer. These percentage values were converted into slope angles by dividing the percentage values by a hundred and an inverse function of tangent gives the slope angle.

Chapter Four: Results and Discussion

Classification of vegetation has been one of widely used methods in vegetation science. Different approaches might be used to classify communities. In some cases classification may employ physiognomically dominant species as they control material cycle and energy flow in the ecosystem (Walter, 1985) or floristically dominant species such as character species as defined by Andreucci et al., (2000). Character species are those that show maximum abundance or frequency in a relevé or groups of relevés. Thus the communities are named after those species, which have mean cover abundance value of greater than 4 (see Appendix 2).

Out of 50 relevés sampled one relevé is considered to be outlier, relevé 21, since it has experienced greater human disturbance such as fire and hence been dominated by species such *Hyparrhenia spp. and Tepherozia sp*. The sampling yields about 174 species belonging to 56 families. Out of these 105 are tree/shrub, 47 herbs, 14 grasses, 7 climbers and 1 fern species have been identified. In terms of families Fabaceae 25 species, Poacae 14 species and families such as Asteraceae, Acanthaceae, Euphorbiaceae, Labiatae and Rubiaceae contains 8 species each while 6 species belong to Combretaceae.

Communities were identified on the basis of relevé grouping by similarity ratio. Five communities were identified as a result of grouping of relevés and designated as communities 1, 2, 3, 4, and 5 as shown in the dendrogram. Likewise the species groups are identified on the basis of correlation coefficients and are designated as species groups 1, 2, 3, 4, 5, 6, and 7. Five communities and seven species groups are described below

4.1 Vegetation Classification: Communities and Species Groups

4.1.1 Communities

1. ***Combretum molle-Euclea devinorium-Dodonea angustifolia*** Community. This community is found at an altitudinal range of 1300m-1650m. The tree shrub layer is dominated by *Combretum molle, Euclea devinorium, Dodonea angustifolia and Terminalia browni*. While in the herb layer *Satureja abyssinica, Justicia calyculata* and *Barleria eranthemoides* dominate. The common grass species in the community are *Hetropogon contortus, Enteropogon macrostachyus and hyparrhenia hirta* in respective order.

2. ***Myrsine africana-Euclea devinorium-Rhus ruspolis*** community. This community is found in between 1600m and 1800m altitudes. *Myrsine africana*, *Euclea devinorium, Rhus ruspolis* and *Combretum collinum* dominate the tree-shrub layer. The other important canopy dominant is *Terminalia browni*. The dominant grass species in this community is *Hyparrhenia diplandra* followed by *Sporobolus pyramidalis* and *Hyparrhenia filipendula*. *Justicia calyculata* and *Ocimum canum* dominate the herb layer. In addition to these climbers such as *Jasminum floribundum*, *Hippocratea africana* and *Vigna membernacea* are observed in this community.

3*.* ***Acalipha fruticosa-Acacia mellifera*** community: This community is found in an altitudinal range of 1250m-1350m. *Acalipha fruticosa*, *Acacia mellifera*, *Acacia tortilis, Rhus natalensis* and *Balanites aegyptica* dominate the tree-shrub layer. *Barleria eranthemoides*, *Melhania ovata* and *plectheranthus barbatus*, *Sansieviera sp*. and *Asparagus flagellaris* dominate the herb layer. Succulent climbers such as *Cissus quadrangularis* are common in this community. Grass species, which are dominant in this community, include *Sporobolus pyramidalis*, *Panicum atrosanquineum* and *Heteropogon contortus*.

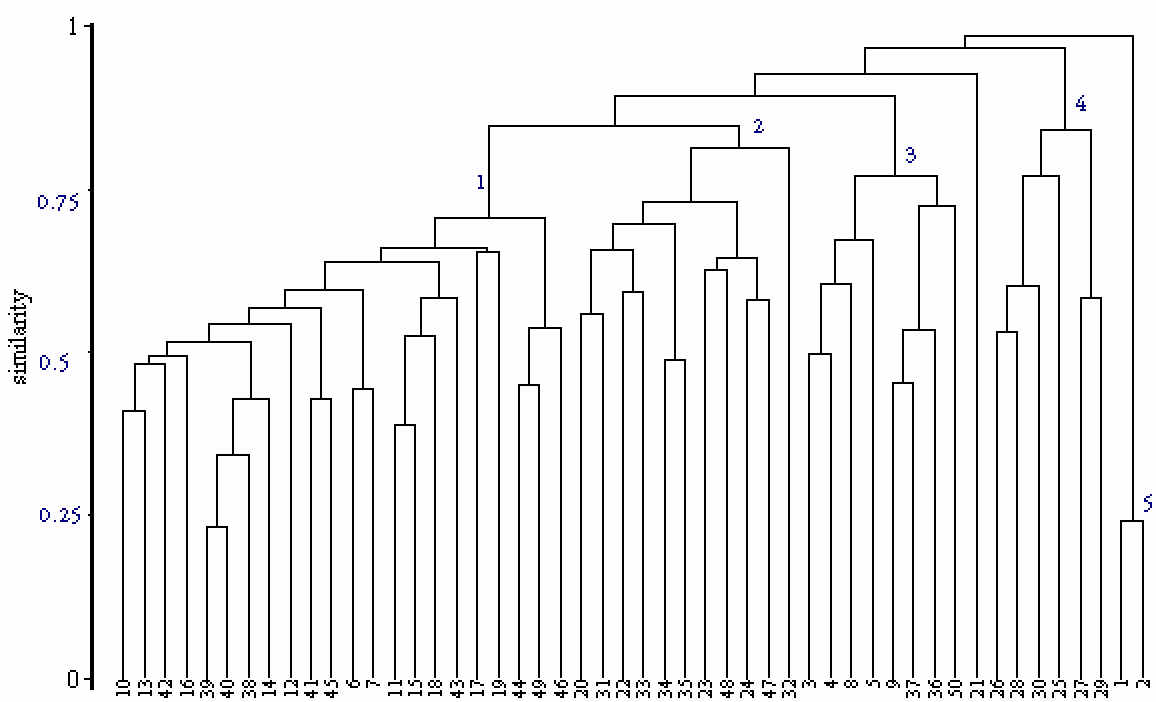


Fig.2: Dendrogram obtained by application of agglomerative Classification Technique at 80% Similarity level. The dendrogram yields five Communities

4. *Erythrina abyssinica-Pittospporum abyssinicum* community: This community is found in between 1800m and 2250m. *Erythrina abyssinica*, *Pittospporum abyssinicum*, *Bersama abyssinica* and *Maesa lanceolata* dominate the tree-shrub layer. However species such as *Galineria saxifragia*, *Hagenia abyssinica* and *Hypericum quartinianum* are commonly observed species in the tree-shrub layer of the community. Woody climbers such as *Rubus stuedneri* tends to have larger cover value in the community. *Acanthus eminens* and *Acanthus pubescens* dominate the herb layer. Moister sites are occupied by *Arundinaria alpina*. Grasses seem to be absent in this community.

The vertical stratification of trees is clearly observed in this community. Tree species such as *Erythrina abyssinica* and *Galineria saxifragia* emerge out as high as 30m while *Maesa lanceolata*, *Bersama abyssinica* and *Hypericum quatinianum* occupy the lower layer. Below this layer again species such as *Pittospporum abyssinicum*, *Acanthus eminens* and *Acanthus pubscens* occupy the ground.

5 Lepidotrichilia volkensi-Isoglossa somalensis-Achyranthus aspera-Ficus sur and Commicarpus plumbiagineus: This community is located at lower altitude in between 1180m and 1250m. *Lepidotrichilia volkensi* and *Ficus sur* dominate the tree layer. The herb layer is completely dominated by *Isoglossa somalensis* and *Achyranthus aspera*. A climber such as *Commicarpus plumbiagineus* is common species with fairly large cover value in this community. However species such as *Croton macrostachyus*, *Prunus africana* and *Solanum incanum* are observed in the tree-shrub layer. On the other hand herb layers do also contain *Asystasia mysorensis* and *Hoslundia oppsita* with relatively lesser cover values.

Lepidotrichilia volkensi and *Ficus sur* dominate in terms of cover and height on the tree layer. These trees attain a height above 30m but the under canopy is generally dominated by herbs excepting the canopy gaps where species such as *Solanum incanum* and seedlings of *Prunus africana* (which has more economic values apart from its wood value: namely in west Africa the barks of *Prunes africana* is used for cancer treatment) were observed. As many as 58 seedlings of *Prunus africana* were counted in a relevé during field survey. This high frequency may probably be due to the dispersal of this species by birds or other animals from other areas. This could possibly be the indication of temporal dynamism of vegetation as the new species invade and subsequently be accumulated in the site (Jacquemyn et al., 2001)

The presence of these big trees (*Lepidotrichilia* and *Ficus*) might probably be related to closer underground water table, where trees can send their roots and tap water in order to cope the aridity of the area. Under the canopy herbs such as *Isoglossa somalensis*, *Achyranthus aspera* and *Asystasia mysorensis* become abundant possibly due to shade effect and nutrients (eg. Phosphorous and Nitrogen) availability where herbs are strong competitors than trees in this regard (Walter, 1985). Therefore according to Walter (1985), herb species occupy flat topography and gentler slopes than trees.

4.1.2. Species Groups

Seven plant species groups are identified on the basis of correlation coefficients. Three character species are used to designate the group within community/ among communities identified earlier. These species groups are designated as 1, 2, 3, 4, 5, 6, and 7.

Species group 1 constitutes species such as *Acaica brevispica-Aeschenomene abyssinica and Cussonia holestii*. This group is found in communities 2 and 3. Species group 2 is *Acalipha fruticosa-Acacia mellifera-Barleria eranthemoides*. It is characterized by *Acalipha fruticosa, Acacia mellifera, Barleria eranthemoides, Acacia tortilis*, *Acacia senegal* and grass species such as *Bothriochloa insculpta*. This association prefers steeper slope and in areas of low stone covers in community 3 (Table 5).

Species group 3 contains species such as *Balanites aegyptica-Canthium setiflorium-Sporobolus pyramidalis*. This species group is dominated by *Balanites aegyptica, Canthium setiflorium, Sporobolus pyramidalis, Acacia nilotica, Asparagus flagellaris, and* prefer to aggregate in community 3 (1250m-1350m).

Species group 4 is dominated by *Combretum molle-Euclea devinorium-Dodonea angusifolia.* In addition to the above dominant species, the composition of the species group includes *Terminalia browni*, *Heteropogon contortus*, *Rhus natalensis*, *Olea europea ssp.Cuspidata* etc. This group contains many species and distributed in larger altitudinal (1250m- 1800m) ranges in Communities 1, 2 and 3.

Species group 5 constitutes species such as *Myrsine africana-Rhus ruspolis-Hyparrhenia diplandra:* This species group, in addition to the dominant species, is composed of *Combretum collinum, Terminalia laxiflora, Albizia gummifera, Maytenus arbutifolia, Calpurnia aurea*,etc. This species group is found largely in community 2 at 1600m-1800m where steeper slope and higher solar radiation as a result of high aspect value (Table 5). The exception to this may be the case of *Myrsine africana*, which is observed in shade environments unlike the others.

Species group 6 is defined by *Erythrina abyssinica-Pittospporum abyssinicum-Bersama abyssinica*. In addition to the dominant species mentioned above, the species group is composed of species such as *Acanthus pubescens, Maesa lanceolata, Galineria saxfragia, Arundinaria alpina*, etc. This species group is found in community 4 at altitudinal range of 1800-2250. This group of species may probably prefer slightly acidic soils (Table 4), lower temperature and relatively high amount of rainfall as can be inferred from higher altitude (Map 2).

Species group 7 is defined by *Lepidotrichilia volkensi-Isoglossa somalensis-Achyranthus aspera*. This species group is composed of species, in addition to the dominant species, such as *Ficus sur, Asystasia mysorensis(Roth.*), *commicarpus plumbiagneus, Prunus africana, Croton macrostachus,* etc. Herb species tend to have larger abundance in this species group. It is found in community 5 at lower elevation along Lakeshore (1180-1250m).

It is, therefore, generally argued that the combinations of species and their responses to the given environment are more informative than a single species (Andreucci et al., 2000, Bell et al., 2000). Bell et al. (2000) also indicated that species are sorted out to the sites, which best suits them hence; species assemblages would be a good indicator of the environments. Thus the groups of plant species that have been discussed would provide some insights regarding the site preference of species groups and the assemblage of a community.

4.2 Altitudinal Gradient of Communities and Diversity

Gradual turnover (change) in species composition and diversity is observed in the study area. Even though communities are identified on the basis of dominant species, there is a cline in composition of species and diversity. Jaccard's coefficient of similarity is computed to see whether communities and species composition grades gradually or in discontinuity.

Table 1: Jaccard's Presence community coefficient among 5 communities

Communities	1	2	3	4	5
1	1.00				
2	0.52	1.00			
3	0.53	0.20	1.00		
4	0.16	0.36	0.07	1.00	
5	0.05	0.07	0.04	0.11	1.00

Jaccard's community coefficient of similarity indicates that species composition similarity among communities is high (Table 1). Community 1 shares more species composition with communities 2, 3 and 4, i.e. 0.52 (52%), 0.53 (53%) and 0.16 (16%) respectively (Table 1). Species composition similarity between community 1 and 5 is low (5%). Community 5 has lower compositional similarity with all other communities because of the location of community 5 in the lakeshore.

Table 2. Jaccard presence community coefficient among adjacent communities/altitudinal ranges

Altitudinal Ranges	Similarity coefficient	Communities
1180-1250/1250-1350	4.05%	3,5
1250-1350/1300-1650	53.3%	1,3
1300-1650/1600-1800	52.77%	1,2
1600-1800/1800-2250	36.36%	2,4

There seem to be abrupt transition between community 5 and 3. Very small proportion of species occurs in two communities in common (4.05%). The transition between community 3 and community 1 is so gradual as 53.3 % of species found in both communities (Table 2). Likewise, communities 1 and 2 have larger number of species in common (52.77%), while there seems relatively rapid decline in similarity of species composition in between communities 2 and 4.

Zonal pattern of community is a widely observed phenomenon in Ethiopia and elsewhere in East African mountains (Lisanework Nigatu, 1987; Zerihun Woldu et al., 1989; Friis, 1992; Weshe, 1999). The pattern observed in this study indicates that community composition turnover is very gradual as exhibited by high similarity coefficients among altitudinal ranges (Table 2); in this regard Friis (1986) has also noted the gradual transition of floristic boundaries in Bale highlands. Even though continuity of vegetation appears to be the case in the area, discontinuity of composition is observed between communities 5 and 3 at an altitude of 1250m and in between communities 2 and 4 at an altitude of 1800m.

Some authors (eg. Friis, 1992) have also indicated that 1300m or a value closer is a critical altitude where community transition occurs in mountainous topography in Africa, especially between lowland forest and montane forest. On the other hand, Zerihun Woldu et al., (1989) have indicated that 1600m and 2350m appeared to be the line of discontinuities of the tree-shrub layer due to the effect of temperature and precipitation. The probable cause of relative abruptness in the transition of communities at 1800m in the study area may also be due to the decline in ambient temperature, soil properties and possibly be the variation in substrate. The highland of Chencha is mainly having tertiary basalt while that of the Rift Valley floor and escarpment is recent volcanic and tuffaceous material of the quaternary (Mohr, 1971; Vukasinovic, 1969). Beals (1969) has pointed out that the discontinuity of communities on the

Bati slope (Wello) as a result of discontinuity of substrate from talus (dominated by *Acacia nubica*) to bedrock [dominated by *Acacia senegal* and *Commiphora erythraea*]

The diversity of species also shows gradual change among communities as altitude increases. Table 3 shows Shannon-Wiener diversity index.

Table 3. Shannon-Wiener Diversity Index (using H= -sum pi ln pi) .

Communities	Richness	Diversity Index(H)	Evenness(H/HMAX)
1	89	3.75	0.835
2	76	3.891	0.898
3	63	3.826	0.923
4	16	2.478	0.894
5	45	3.527	0.927

Species richness is among the most widely used measures of diversity (Tivy, 1993). Species richness refers to the number of species present in a given area or habitat (Tivy, 1993). Based on this measure community 1 has high species richness while community 4 is a species poor one. The species richness follows bell shaped pattern along altitudinal gradients. The pattern maintains peak at intermediate elevation and tends to taper away in both directions (Table 3).

Species evenness measures the equity of species in a given sample area or it is the opposite of dominance by few species. In other words species evenness measures the relative or proportional abundance of species in the sample area. Hence, low evenness value indicates the dominance of the environment by few species (Zerihun Woldu et al., 1999). In this regard, communities 5 and 3 have more even representation of overall species followed by communities 2 and 4 (Table 3). Community 1 has high richness but lowest evenness.

In terms of the Shannon-Wiener diversity index, Community 2 and community 3 have highest species diversity (3.89 and 3.82) followed by community 1 and 5 (Table 3). Community 4 has lowest species diversity and richness than others. The greater heterogeneity of species in communities 2 and 3 could probably be due to environmental heterogeneity as it is the case elsewhere (Cowling et al., 1998).

4.3 The Relationship between Communities and Soil Properties

Soil physical and chemical properties influence plant growth in many ways such as moisture availability, nutrient availability and Cation Exchange Capacity. The test for variance of soil physical and chemical properties (Table 4) reveals that the differentiation of communities can be partly explained by the variations of soil texture and chemical properties at $p<0.05$ level of significance, excepting Cation Exchange Capacity (Appendix 3).

Table 4: Mean values of Soil Physical and Chemical properties and ANOVA (F ratio at $P<0.05$) df= 4 and 44

Soil properties	Community 1 1300-1650	Community 2 1600-1800m	Community 3 1250-1350m	Community 4 1800-2250m	Community 5 1180-1250m	F ratio ($P<0.05$)
%Sand	34.39	30.21	50.50	33.07	19.98	4.87
% Silt	25.60	24.72	32.65	31.20	40.02	2.67
% Clay	40.62	45.05	16.84	35.72	40.06	6.62
Textural class	Clay	Clay	Sandy loam	Clay loam	Silty Clay	
PH	6.63	6.33	7.23	5.83	7.40	6.41
CEC	44.55	39.64	46.51	40.53	35.30	1.03
%Organic Matter	2.90	2.84	2.03	3.72	5.52	3.59
%Total Nitrogen	2.53	2.59	2.97	2.83	0.25	4.45
Pppm	1.25	2.83	3.14	4.43	96.63	854.46

Physical Properties of Soils Vs Communities

As indicated in Table 4, the mean values for soil particle size distribution is highly variable. The proportion of sands in community 3 is highest and it is lowest in community five. The proportion of silt is high in community 5 (40.02%). The variation of silt among communities is low thus its influence regarding community differentiation is slightly weak as F value indicates at $p<0.05$ level of significance. The proportion of clay particle size is highest in community 2 (45.05%) while it is lowest in community 3 (16.84%), (Table 4). In terms of textural classes communities 1 and 2 have clay-textured soils. Community 5 is silt dominated clay type of soils (Silty clay) while communities 3 and 4 have sandy loam and clay loam textured soils. The test for significance of variation of soils physical properties exhibits that soil particle size distribution explains some variation in communities. There is significant variation of sand and clay particle size distribution but the variation in the percentage distribution of silt size particle is not strongly varied at 0.05 level of significance.

Chemical properties of soils Vs Communities

There is a significant variation in soil chemical properties (excepting Cation Exchange Capacity) among communities at 0.05 level of significance (Table 4). The mean pH values for five communities range between 5.83 and 7.4 hence soils have acidic to slightly basic reaction. Community 4, 2 and 1 are found in slightly acidic soils while community 3 and 5 are found in neutral to very slightly basic soil reaction.

Percentage organic matter content and total nitrogen also vary among communities. In decreasing order of soil organic matter communities 5, 4, 1, 2 and 3 while total percentage nitrogen in decreasing order of magnitude include communities 3, 4, 2, 1 and 5 and available phosphorous (ppm) in decreasing order is communities 5, 4, 3, 2, and 1.

High species diversity in communities 1, 2, and 3 (Table 3) could partly be due to the low available phosphorous and total nitrogen content of the soils. This agrees with the generally held belief that highly nutrient rich soils would tend to support low species diversity (Huston, 1994). Hall and Swaine (1976 cited in Huston 1994, pp 515) also reported the negative relationship between species richness and soil nutrients for 155 forest cites in Ghana. Community 4 has low heterogeneity and low species richness probably due to the low soil pH, higher nitrogen content of the soil apart from the obvious effect of temperature gradient. The high phosphorous content (96.63ppm) in community 4 could probably due to geomorphic influences in the lower slope position (Map 2). Murphy (1968) and Vukasinovic (1969) have also reported the presence of high level of available Phosphorous (61.1 mg/100gm soil) in Arbamicnh area.

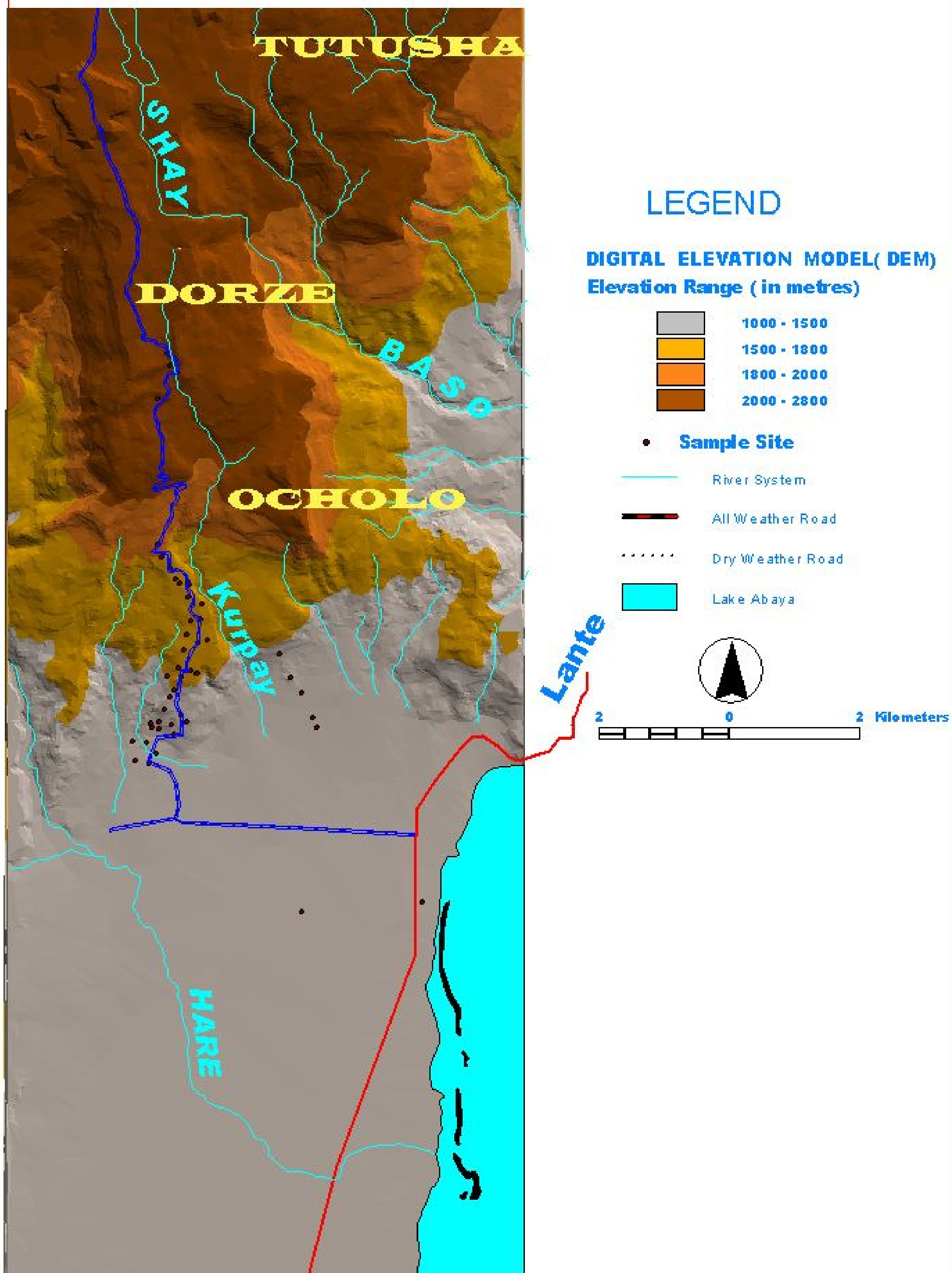
4.4 The Relationship between Communities and Topographic Features

Table 5: Comparison of Topographic Features and Communities ($P<0.05$) df=4 and 44

Topographic Feature	Community 1	Community 2	Community 3	Community 4	Community 5	F Ratio
%Surface Stone Cover	52.22	30.91	17.87	34.83	0	7.71
Slope steepness (°)	5.91	8.36	8.5	6.83	1	4.285
Aspect	1.72	2.34	2.01	2.42	-1	4.81

Community 5 is found in level ground where the effect of slope aspect in controlling solar radiation appears to be negligible (Table 5). Community 4 has high slope aspect and fairly high percentage surface stone cover while the effects of these two environmental factors may not be important to make a distinct community (4). The effect of slope aspect as a control of radiation may not appear to be pronounced due to the counter balancing of these by higher amount of rainfall in the high altitude and the slope orientation towards a moisture laden southwest equatorial monsoon winds. More probable reason for the low diversity and richness of species in community 4 could possibly be climate-related water energy relationships within relatively higher altitude (1800-2250m) and factors related to the soils.

Communities 2 and 3 have low stone cover and high slope steepness, which may imply soil moisture stress and variability is implied, therefore the high heterogeneity of species in this community may partly be due to moisture stress. The presence of succulent species such as *Sansievieria sp*. (leaf succulent), *Asparagus flagellaris* (root succulent), *Aloe otalensis* and climber succulent such as *Cissus quadrangularis* in community 3 may be good indicators of moisture stress.



Map 2 : DIGITAL ELEVATION MODEL

Chapter Five: Conclusions and Recommendations

The five communities identified are designated as communities 1, 2, 3, 4 and 5. This includes: 1. *Combretuem molle-Euclea devinourium-Dodonea angustifolia* community at 1300-1650m elevation. 2. *Myrsine africana-Euclea devinorium-Rhus ruspolis* community at 1600-1800m-elevation range. 3. *Acalipha fruticosa-Acacia mellifera* community at 1250-1350m. 4. *Erythrina abyssinica-Pittospporum abyssinicum* community at higher elevation (1800m-2250m). 5. *Lepidotrichilia volkensi-Isoglossa somalensis-Achyranthus aspera-Ficus sur-Commicarpus plumbiagineus* community at 1180-1250m.

The seven species groups are also designated as species groups 1, 2, 3, 4, 5, 6 and 7. Their names are based on the first three character species in terms of mean cover abundance value (Appendix 2). They include: Species group 1 is characterized by *Acacia brevispica-Aeschenomene abyssinica-Cussonia holstii* in communities 3 and 2; Species group 2 includes *Acalipha fruticosa-Acacia mellifera-Barleria eranthemoides* groups which are found in community 3 where slope is steeper, low stone cover (17.87%), sandy loam texture and in neutral soil reaction (Table 5 and Table 4). Species group 3 is defined by *Balanites aegyptica-Canthium setiflorium-Sporobolus pyramidalis*, which is found mainly in community 3, while species group 4 is characterized by *Combretum molle-Euclea devinorium-Dodonea angustifolia*. This species group contains many species and widely distributed in communities 1, 2 and 3 at elevational range of 1250-1800m. Species group 5 is characterized by *Myrsine africana-Rhus ruspolis-Hyparrhenia diplandra*. This species group is found in community 2 in steeper slopes.

Species group 6 is characterized by *Erythrina abyssinica-Pittospporum abyssinicum-Bersama abyssinica*. This species group prefers slightly acidic soils (pH, 5.83), lower temperature and high moisture at higher elevation (1800-2250m). Species group 7 is defined by *Lepidotrichilia volkensi-Isoglossa somalensis-Achyranthus aspera*. The canopy layer in this species group is dominated by *Lepidotrichilia volkensi* and the ground is completely dominated by herbaceous species such as *Isoglossa somalensis and Achyranthus aspera*. This species group is found in community 5 at lower elevation (1180-1250m). The community is largely dominated by herbaceous species and this may probably be due to the availability of nutrients and topographic moisture in the lower slopes.

Communities' grade gradually along altitude in the study area as indicated by the high percentage of species composition in adjacent communities (Table 2). However, relatively abrupt change in species composition between communities 5 and 3, and communities 2 and 4 is observed. The probable reason for this dissimilarity in composition for communities between 2 and 4 could be the low soil pH, lower temperature and high rainfall in higher elevation (1800-2250m).

The diversity of species also shows a gradual decline as altitude increases as indicated by Shannon-Wiener diversity index (Table 3). Yet it seems to maintain mid-elevational peak at communities 1-3 (1250-1800m). A number of factors might have contributed to the high diversity in the mid-elevational range. The effect of altitude could be the first item to bring such phenomena as it affects temperature and moisture directly and through its indirect effect on slope, aspect, stone cover and so on.

Generally in this study environmental heterogeneity is given more weight to understand the variation of communities along complex gradient of altitude. However, at local scales species competition, plant to plant interaction and other biological process might have played a significant role in the structuring of communities and diversity equally or more important than environmental heterogeneity. In addition to this local species richness and community composition is affected by local dispersal and some other processes at larger geographical scales. A good understanding for the community organization and diversity is therefore calls for an investigation of the site heterogeneity, and other biological process and mechanism of dispersal in a given geographical area

Recommendations

1. Community 5 is found along the Lakeshore where disturbance is observed, big trees such as *Ficus sur* are cut down for lumber making and the adjacent forest is cleared for cultivation of Banana nearby. Therefore, this community should be included in the Nech Sar National Park before its elimination. In this regard alternatives for the shift in land use should be considered for maintaining the livelihood of the people. The options may include the development of eco-tourism, which could be designed to serve for both nature conservation and generate income for the surrounding population.

2. Communities 1, 2 and 3 have high diversity and species richness. These communities are found in relatively steeper slopes at the escarpment of the Rift Valley and adjacent highland of Chencha. These communities should not be subjected to more disturbances as the fragile environment can easily be degraded. The protection of these communities, by Zonal agricultural bureau, in such slopes has advantages to maintain community 5 in the lower slope position along the lakeshore due to the effect of sediment load.

3. Community 4 is found at higher elevation as a patch. This is the result of highland agricultural activities perhaps for many years of settlement. Maintaining this community is very essential even within these patchy environments so that the highland forest may not be eliminated from the areas as it can serve as a 'genetic pool' in the region before the total replacement of the forest by exotic trees such as *Eucalyptus globulus* or *Cupressus lustianica*.

4. It is suggested that further investigation of the vegetation-environment relationships is essential by considering factors such as moisture, ambient temperature, disturbance and dispersal effects in community organization and diversity.

5. The study area supports different vegetation types so that the conservation of this vegetation types should be given the priority concern for the conservation of biodiversity.

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APPENDIX 1

Species Name	Family
Abutilon fruticosum	Malvaceae
Acacia brevispica	Fabaceace
Acacia etbiaca	Fabaceace
Acacia hockii	Fabaceace
Acacia mellifera	Fabaceace
Acacia nilotica ssp. Leiocarpa Brenan	Fabaceace
Acacia senegal (L.)Willd	Fabaceace
Acacia tortilis (Forssek) Hayne	Fabaceace
Acalipha fruticosa	Euphorbiaceae
Acanthus eminens	Acanthaceae
Acanthus pubescens	Acanthaceae
Achyranthus aspera	Amaranthaceae
Acokanthera schimperi	Apocynaceae
Aeschynomene abyssinica (A. Rich) Vatake	Fabaceace
Albizia gummifera	Fabaceace
Albizia schimperiana Oliv.	Fabaceace
Allophylus abyssinicus(Hochst.) Radlkofer	Sapindaceae
Aloe otalensis	Aloaceae
Aristida adscensionis L.	Poacea
Arundinaria alpina	Poacea
Asparagus flagellaris Baker	Asparagus
Aspilia mozambiqensis	Asteraceae
Asplenium bugoiense	Aspleniaceae
Asystasia mysorensis (Roth.)	Acanthaceae
Balanites aegyptica	Balanitaceae
Balanites rotindifolia	Balanitaceae
Barleria eranthemoides	Acanthaceae
Bartisia petitiana A. Rich	Scrophylariaceae
Becium grandiflorium (Lam.) Pichi-Sermolli	Labiatae
Bersama abyssinica	Melianthaceae
Bidens schimperi	Asteraceae
Boscia angustifolia	Capparidaceae
Bothriochloa insculpta (Hocst. Ex A. Rich)	Poacea
Bothriocline schimperi	Asteraceae
Bridelia micrantha (Hocst) Baill.	Euphorbiaceae
Cadaba farinosa (Forssek.)	Capparidaceae
Calpurnia aurea	Fabaceace
Canthium oligocarpum Heirn	Rubiaceae

Canthium setiflorium Heirn	Rubiaceae
Carisa edulis	Apocynaceae
Chloris roxburghiana Schult.	Poacea
Cissus quadrangularies	Vitaceae
Clausena anisata Willd.	Rutaceae
Clutia abyssinica	Euphorbiaceae
Combretum aculeatum Vent.	Combretaceae
Combretum collinium Fress.	Combretaceae
Combretum molle	Combretaceae
Combretum sp.	Combretaceae
Commicarpus plumbiagineus (Cav.) Standl.	Nyctaginaceae
Commiphora africana A. Rich	Burseraceae
Commiphora habessinica(Berg.)	Burseraceae
Commiphora terebinthina	Burseraceae
Conyza schimperi A. Rich	Asteraceae
Cordia africana	Boraginaceae
Crotlaria laburnifolia L.ssp.laburnifolia	Fabaceace
Crotolaria incana	Fabaceace
Croton machrostachus Del.	Euphorbiaceae
Cussonia holsti Harms ex Engl.	Araliaceae
Cyathula achyranthoides (H.B.K) Moq.	Amaranthaceae
Cyathula cylinderica Moq.	Amaranthaceae
Desmodium barbatum (L.) Benth.	Fabaceace
Desmodium repandum	Fabaceace
Desmodium velutinum (Willd.) DC	Fabaceace
Dichrostachys cinerea	Fabaceace
Dissotis senegambiensis	Melastomataceae
Dodonea angustifolia	Sapindaceae
Dovyalis verucosa	Flacourtiaceae
Dracaena stuedneri	Agavaceae
Ehertia cymosai	Boraginaceae
Enterepogon macrostachyus (Hochst. Ex. A. Rich)Benth	Poacea
Erianthemum dregei ssp. Dregei	Loranthaceae
Erytrina abyssinica	Fabaceace
Eucalyptus globulus	Myrtaceae
Euclea devinorium	Ebenaceae
Euphorbia obovalifolia	Euphorbiaceae
Ficus capraefolia Del.	Moraceae
Ficus glumosa Del.	Moraceae
Ficus platyphylla	Moraceae
Ficus sur	Moraceae

Flacourtia indica	Flacourtiaceae
Fluggea virosa	Euphorbiaceae
Galineria saxfragia	Rubiaceae
Galium spurum	Rubiaceae
Gardenia ternifolia	Rubiaceae
Geranium arabicum Forssek.	Geraniaceae
Gomphocarpus linarifolus	Asclepiadaceae
Grewia bicolor	Tiliaceae
Grewia vilosa	Tiliaceae
Hagenia abyssinica	Rosaceae
Hallea rubrostipulata (K. Shum.) J.F. Leroy	Rubiaceae
Harrisonia abyssinica Oliv.	Simaroubaceae
Helichrysum odoratissium L. Less	Asteraceae
Helinus integrifolius (Lam.) Kuntze	Rhamnaceae
Heteropogon contourts (L.) Roem.and shult	Poacea
Hibiscus crasinervines	Malvaceae
Hibscus micharantus L.f.	Malvaceae
Hippocratea africana	Celasteraceae
Hoslundia opposita Vahl.	Labiatae
Hyparrhenia collina (pilg.) Stapf.	Poacea
Hyparrhenia diplandra(Hack.) Stapf.	Poacea
Hyparrhenia filipendula (Hochst) Stapf	Poacea
Hyparrhenia hirta	Poacea
Hypericum quaritinianum	Hyprericaceae/Clusiaceae
Hypoestus forskalei (Vahl.) Roem & Schult.	Acanthaceae
Indigofera atriceps	Fabaceace
Isoglossa somalensis	Acanthaceae
Jasminum abyssinicus	Oleaceae
Jasminum floribundum R.Br.	Oleaceae
Justicia calyculata Deflers.	Acanthaceae
Justicia glabra Koening ex. Roxb	Acanthaceae
Kalanchoe crenata (Andr.) Haw	Crassulaceae
Lantana camara	Labiatae
Lepidotrichilia volkensi	Meliaceae
Lippia adoensis Hochst ex Walp.	Verbenaceae
Luecas stachydiformis	Verbenaceae
Maeosa lanceolata	Myrsinaceae
Manilkara butugi Chiov.	Sapotaceae
Maytenus arbutifolia	Celasteraceae
Maytenus senegalensis	Celasteraceae
Melhania ovata (cav.) Spreng.	Sterculiaceae

Myrica salicifolia	Myricaceae
Myrsine africana	Myrsinaceae
Ocimum canum	Verbenaceae
Ocimum urticifolium Roth.	Verbenaceae
Olea europea ssp Cuspedata	Oleaceae
Olea welwitschii	Oleaceae
Osyris lanceolata Hoscst	Santalaceae
Ozoroa insignis Del.ssp. Insignis	Anacardiaceae
Panicum atrosanquineum A. Rich	Poacea
Panicum maximum Jacq.	Poacea
Papea capensis	Sapindaceae
Pavetta oliverana Heirn.	Rubiaceae
Pavetta sp.	Rubiaceae
Phyllanthus ovalifolius Forssek	Euphorbiaceae
Pittospporum abyssinicum	Pittospporaceae
Plecthranthus assurgens(Baker) Morton	Labiatae
Plecthranthus barbatus Andr.	Labiatae
Pluchea dioscoridis Dc.	Asteraceae
Polycis fulva (Heirn)	Araliaceae
Premna schimperi Engl.	Verbenaceae
Prunus africana	Rosaceae
Pychnostachys abyssinica Fresen	Labiatae
Rhamnus prinoides L' Herit	Rhamnaceae
Rhamnus stado A. Rich	Rhamnaceae
Rhus natalensis	Anacardiaceae
Rhus ruspolis	Anacardiaceae
Rhus vulgaris Mikle	Anacardiaceae
Ricinus communis L.	Euphorbiaceae
Rubus Stuedneri	Rosaceae
Sansevieria sp.	Agavaceae
Satureja pseudosimensis	Labiatae
Scheffleria abyssinica	Araliaceae
Senna septmtrionalis	Fabaceace
Setaria sphacelata (Schumach) Moss	Poacea
Setureja abyssinica Benth.	Labiatae
Solanium incanum	Solanaceae
Sporobolus pyramidalis Beauv	Poacea
Steganotaenia araliaceae	Apiaceae
Striga gesnerioides (Willd.) Vatke	Scrophulariaceae
Syzygium guineense ssp. Macrocarpum(Engl.) F. White	Myrtaceae
Tepherosia emeriodes A.Rich	Fabaceace

Tephrosia elata Defl. Var. elata	Fabaceace
Terminalia browni	Combretaceae
Terminalia laxiflora Engl. Et. Diels	Combretaceae
Trifolium quartinianum A. Rich	Fabaceace
Urera hypselodendron (A. Rich) Wedd.	Urticaceae
Vernonia filigera Oliv.& Heirn	Asteraceae
Vernonia trubinata Oliv.& Heirn	Asteraceae
Vigna memberanceae	Fabaceace
Ximenia americana	Olacaceae
Zehneria scabra (L.f) Sond.	Cucurbitaceae
Zizypus mucronata	Rhamnaceae
Zornia setosa Bak.F.	Fabaceace

APPENDIX 2: Synopsis of the Communities and Species Groups

Species Groups (1-7)	Communities				
	1	2	3	4	5
1					
Acacia brevispica	.000	.545	1.375	.000	.000
Cussonia holstii	.091	.364	.000	.000	.000
Aeschenomene abyssinica	.091	.455	.250	.000	.000
2					
Acacia Senegal	.091	.000	2.875	.000	.000
Acacia tortilis	.000	.000	3.500	.000	.000
Acacia mellifera	**.182**	**.000**	**5.125**	**.000**	**.000**
Acalipha fruticosa	**.273**	**.000**	**5.250**	**.000**	**.000**
Barleria eranthemoides	.455	.000	3.750	.000	.000
Cissus quadrangularies	.045	.000	1.875	.000	.000
Commiphora habessinica	.091	.000	1.500	.000	.000
Kalanchoe crenata	.045	.000	.625	.000	.000
Grewia vilosa	.045	.000	1.250	.000	.000
Acokanthera schimperi	.091	.455	.875	.000	.000
Commiphora africana	.000	.000	1.000	.000	.000
Aloe otalensis	.045	.000	1.375	.000	.000
Commiphora terebinthina	.136	.000	1.375	.000	.000
Plecthranthus barbatus	.091	.000	1.750	.000	.000
Aristida adscensionsis	.136	.000	1.000	.000	.000
Abutilon fruticosum	.364	.000	1.500	.000	.000
Bothriochloa insculpta	.682	.000	1.750	.000	.000
Ficus platyphylla	.045	.000	.125	.000	.000
3					
Asparagus flagellaris	.455	.000	1.625	.000	.000
Canthium setiflorium	1.454	.000	2.750	.000	.000
Balanites aegyptica	.000	.000	3.000	.000	.000
Melhania ovata	.091	.000	2.000	.000	.000
Sansievieria sp.	.000	.000	1.375	.000	.000
Jassminum abyssinicus	.000	.000	1.250	.000	.000
Sporobolus pyramidalis	.273	1.000	2.250	.000	.000
Panicum atrosanquineum	.000	.000	1.125	.000	.000
Unidentified sp.	.136	.273	.375	.000	.000
Acacia nilotica	.591	.000	2.125	.000	.000
Becium grandiflorium	.000	.000	.250	.000	.000
Hibiscus micrantus	.000	.000	.250	.000	.000
Fluggea virosa	.091	.000	.250	.000	.000
Cadaba farinosa	.000	.000	.250	.000	.000
Combretum sp.	.136	.000	.375	.000	.000
4					
Acacia hockii	2.454	.455	1.500	.000	.000
Hyparrhenia hirta	2.091	.000	.750	.000	.000
Dichrostachys cinerea	2.318	.545	.875	.000	.000
Heteropogon contourts	3.546	.000	2.000	.000	.000
Combretum molle	**5.500**	**1.000**	**.875**	**.000**	**.000**
Dodonea angustifolia	**4.273**	**.182**	**.000**	**.000**	**.000**
Olea europea ssp.Cuspidata	3.046	1.000	.000	.500	.000
Carisa edulis	2.318	.273	1.250	.000	.000
Euclea devinorium	**5.227**	**4.545**	**2.875**	**.500**	**.000**
Setaria sphacelata	.455	.091	.000	.000	.000

Species Group 4	Communities 1	2	3	4	5
Tepherosia emeriodes	2.273	.818	.125	.000	.000
Terminalia browni	3.773	2.454	2.500	.833	.000
Combretum aculeatum	.318	.000	2.250	.000	.000
Boscia angustifolia	.136	.000	.625	.000	.000
Grewia bicolor	2.318	1.091	2.875	.000	.000
Rhus natalensis	3.273	1.636	3.250	.000	.000
Harrisonia abyssinica	1.273	.000	1.250	.000	.000
Crotlaria laburnifolia	.227	.000	.375	.000	.000
Enterepogon macrostachyus	2.364	.000	.750	.000	.000
Papea capensis	.500	.091	.000	.000	.000
Ximenia americana	.773	.364	.875	.000	.000
Jasminum floribundum	1.227	1.182	.375	.000	.000
Myrica salicifolia	.591	.000	.000	.000	.000
Lantana camara	.545	.091	.000	.000	.000
Tepherosia elata	.727	.455	.000	.000	.000
Gomphocarpus linarifolia	.318	.000	.000	.000	.000
Manilkara butugi	.909	.545	.000	.833	.000
Maytenus senegalensis	1.454	.545	.000	.000	.000
Ozoroa insignis	.955	.364	.000	.000	.000
Gardenia ternifolia	.364	.545	.000	.000	.000
Setureja abyssinica	.591	.818	.000	.000	.000
Flacourtia indica	1.364	.636	.125	.500	.000
Luecas stachydiformis	.318	.273	.000	.000	.000
Osyris lanceolata	1.227	1.273	.500	.000	.000
Hyparrhenia filipendula	.545	.545	.000	.000	.000
Desmodium velutinum	.318	.273	.000	.000	.000
Bridelia micrantha	.318	.364	.000	.000	.000
Dissotis senegambiensis	.136	.364	.000	.000	.000
5					
Acacia etbiaca	.091	.000	.000	.000	.000
Zizypus mucronata	.136	.091	.125	.000	.000
Pavetta sp.	.045	.091	.000	.000	.000
Justicia calyculata	.136	.909	.625	.667	.000
Calpurnia aurea	.000	1.909	.000	.333	.000
Rhus vulgaries	.000	.545	.000	.000	.000
Eucalyptus globulus	.000	.636	.000	.000	.000
Crotolaria incana	.000	.818	.000	.500	.000
Albizia gummifera	.045	2.546	.000	.000	.000
Helichrysum odoratissium	.000	.818	.000	.333	.000
Terminalia laxiflora	.136	2.091	.000	.000	.000
Clutia abyssinica	.273	1.091	.000	.333	.000
Combretum collinum	.864	2.727	.000	.667	.000
Rhus ruspolis	**1.182**	**4.273**	**.000**	**.833**	**.000**
Myrsine africana	**.773**	**5.091**	**1.000**	**1.000**	**.000**
Maytenus arbutifolia	.409	2.091	.000	1.500	.000
Hippocratea africana	.136	.636	.000	.500	.000
Clausena anisata	.000	.364	.000	.000	.000
Rhamnus stado	.045	.455	.000	.000	.000
Vigna membernacea	.455	.727	1.000	.000	.000
Hyparrhenia diplandra	.318	3.546	.000	.000	.000
Indigofera atriceps	.091	1.091	.000	.000	.000
Pluchea dioscoridis	.000	.455	.000	.167	.000
Hyparrhenia collina	.000	.455	.000	.000	.000

Species Group	Communities				
6	**1**	**2**	**3**	**4**	**5**
Acanthus eminens	.000	.000	.000	1.667	.000
Euphorbia obovalifolia	.000	.000	.125	.500	.000
Pavetta oliveriana	.000	.000	.000	1.000	.000
Hagenia abyssinica	.000	.000	.000	1.833	.000
Erythrina abyssinica	**.455**	**.364**	**.000**	**5.000**	**.000**
Syzygium guineense	.000	.636	.000	1.833	.000
Arundinaria alpina	.000	.000	.000	2.333	.000
Galineria saxifragia	.000	.000	.000	2.667	.000
Albizia schimperiana	.000	.273	.000	1.000	.000
Acanthus pubescens	.000	1.000	.000	3.500	.000
Maesa lanceolata	.000	.000	.000	3.167	.000
Bersama abyssinica	.000	.545	.000	3.500	.000
Conyza schimperi	.000	.273	.000	1.333	.000
Ocimum urticifolium	.000	.818	.000	2.500	.000
Aspilia mozambiqensis	.091	.182	.000	1.500	.000
Asplenium bugoinsis	.000	.000	.000	1.333	.000
Hallea rubrostipulata	.000	.091	.000	.500	.000
Hypericum quaritinianum	.045	.545	.000	1.000	.000
Rubus stuedneri	.000	.000	.000	2.833	.000
Pittospporum abyssinicum	**.136**	**.364**	**.000**	**4.333**	**.000**
Allophylus abyssinicus	.091	.273	.000	1.333	1.500
Hoslundia opposita	.091	.455	.375	1.000	2.500
Cordia africana	.000	.000	.000	.833	2.000
Hibiscus crasinervines	.000	.000	.000	.833	.000
Ficus glumosa	.000	.182	.000	.833	.000
Rhamnus prinoides	.000	.000	.000	.833	.000
7					
Asystasia mysorensis	.045	.000	.750	.000	5.000
Achyranthus aspera	**.000**	**.000**	**.000**	**.000**	**6.500**
Lepidotrichilia volkensi	**.000**	**.000**	**.000**	**.000**	**7.500**
Isoglossa somalensis	**.000**	**.000**	**.000**	**.000**	**7.000**
Prunus africana	.000	.000	.000	.000	5.000
Commicarpus plumbiagineus	**.000**	**.000**	**.000**	**.000**	**6.000**
Ehertia cymosa	.000	.000	.000	.333	1.500
Croton macrostachus	.000	.727	.000	1.500	4.500
Ficus sur	**.000**	**2.727**	**.000**	**.000**	**6.000**
Ocimum canum	.182	1.091	.000	.000	3.500