AN ECOLOGICAL STUDY OF THE VEGETATION OF CHOKE MOUNTAIN, EAST GOJAM, ETHIOPIA.

A Thesis Presented to the School of Graduate Studies
Addis Ababa University

In Partial Fulfillment of the Requirements of the Degree of
Master of Science in Biology

By

Meseret Chimdessa

June 2000

ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

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Abstract

Vegetation of Choke Mountain was studied. Vegetation data of sixty sample plots from five transects were taken from October to November 1999. These were subjected to cluster analysis by distance optimization. Five distinct clusters were obtained. Soil Samples were also collected and analyzed. Results of soil analyses and other environmental variables were compared among clusters. Total nitrogen, exchangeable potassium, percent particle fractions, altitude and slope showed significant difference among clusters. Based on the investigation, Recommendation towards the conservation of natural Vegetation of the area is also given.

1. Introduction

Mountains are areas `characterized by a relief, which results in altitudinal, ecological, climatic, and land use differentiation from surrounding lowland areas (Messerli et al., 1988).

The highlands and mountain areas of Ethiopia are separated into North West and South East by the Rift Valley (Uhlig, 1988). They constitute more than half of all the highland areas of Africa where highlands above 1500 m comprise 43% or 537,000 km^2 (Grosijean and Messerli, 1988).

The mountainous regions of the country are considered as regions where there are extensive areas of land above 2500 m and where many mountain peaks rise to over 4000 m (Daniel, 1977).

Land over 3000 m occupies about 1,589, 000 ha or 1.3% of the total area of the country. Most of these are located in the Administrative regions of Welo, Bale, Arsi, Gonder and Gojam (Daniel, 1988). These mountainous regions of Ethiopia (i.e., those above 3000 m) consist of two ecological belts: sub afroalpine and afroalpine each of which supports unique vegetation. The mountains are natural water catchment areas that serve as important sources of water for permanent streams and rivers. Their vegetation and soil

absorb rainwater and release it slowly into rivers and streams draining to the low-lying lowlands. The vegetation cover also prevents soil erosion, provides shelter and food to the animal life. According to Yalden (1983) they are one of the major centers of faunal and floral diversity with high number of endemics. They generate numerous natural processes vital to human existence, and support an important reservoir of genetic resources (Uhlig, 1988). Due to the steepness of their topography they are also highly fragile and susceptible to soil erosion and degradation. Many of them are highly degraded or show strong tendencies to degradation.

Due to extreme climatic conditions, soil and grassland productivity at these higher altitudes (> 3000 m) is relatively low. However, increasing human population has led to over exploitation of these areas. Agricultural practices are expanding from gentle sloping land in the highlands onto the steeper slopes of the mountains. Crop cultivation is being practiced at elevation close to 3500 m irrespective of low yields expected at these altitudes. These agricultural practices will lead to the further destruction of the fragile environment at the higher altitudes.

Grazing by livestock is also a major problem. The ericaceous belt above the timberline is often burned and used for grazing animals. Human activities such as cutting of plants growing to tree size such as *Hypericum revolutum* and shrubs such as *Erica arborea* and *Euryops pinifolius* for fuel, charcoal production, and construction purposes rendered many of these areas to be highly degraded.

Any alteration of the vegetation through human activity and the accompanied changes in land use brings undesirable effects on the water resources of the mountains (Brown, 1973). Destruction of their vegetation adversely affects the biodiversity including both the endemic and non-endemic organisms and contributes to loss of biodiversity.

For the sustainable use of these belts, and maintenance of faunal and floral diversity, planning and implementation of appropriate management techniques are required. These in turn depend on the knowledge of the status and diversity of species composition that can be achieved through the documentation of plant species and description of plant communities. Various researchers have carried out such ecological studies on afroalpine vegetation of Ethiopia over the years. Hedberg (1964, 1986) described the different plant life forms and principal plant communities in most of the highlands of East Africa including Ethiopia. Miehe and Miehe (1994) studied plant communities of the ericaceous belt on Bale Mountains; Minassie Gashaw and Masresha Fetene (1996) have also made a description of plant communities on Senatti plateau of the Bale Mountains.

However, the vegetation in most of the afroalpine zones in the northern part of Ethiopia has not been studied. Choke mountain, which generally rise to over 3000 m and some peaks reaching above 4000 m is one such mountain. So far, there is no detailed ecological study conducted on the vegetation of this mountain. This study is, therefore, an attempt to look into the species composition and plant community in the Choke Mountain, which is hopped to contribute to our knowledge of the afroalpine zone in northern Ethiopia.

Classification and ordination are some of the methods used in vegetation description. These two approaches towards vegetation description are allegedly based on quite different concepts of the essential nature of vegetation. There are some plant sociologists who regard a plant community as a complex or quasi-organism whilst others regard a plant community in an individualistic community concept. The concept of a complex organism implies some considerable interrelationship between species of a community, which in growing together, sufficiently modify an environment to form a recognizable and repetitive vegetation grouping. The advocators of this concept use classification as a natural method in vegetation description. Conversely the individualistic hypothesis implies that no two communities are strictly identical in their detailed composition and therefore can not be readily delimited as clear-cut units. Plant sociologists of this view use ordination techniques for describing their vegetation (Anderson, 1965; Kershaw, 1973).

Classification

A classification aims at grouping individual stands into categories. The stands that are closely similar with one another form one class, which are separated from other such classes that also consist of similar stands of their own. The properties common to a group of similar stands in a class are then used to describe that class (Muller-Dombois and Elenberg, 1974).

Hierarchical, reticulate and table sorting methods are some of the classificatory systems. Hierarchical classification explains the relationships between the different clusters in hierarchic fashion. The classes at any one level are subclasses of classes at a higher level. Ordinary taxonomic classification with such levels as orders, families, genera, and species is an example of such type (Pileou, 1969). A hierarchical procedure does not yield classification directly but leads in the first place to the construction of a tree diagram or dendrogram showing how the entities being classified are assumed to be interrelated. The classes to be recognized are then decided by examining the dendrogram. In a reticulate classification (Pielou, 1969), the clusters are defined separately and the links between them have the form of a network rather than a tree.

A hierarchical classification system can be divisive or agglomerative. In a divisive method, classification begins with the whole quadrat collection, which is then divided and subdivided in order to arrive at the ultimate classes. In agglomerative method, classification begins at the bottom and work upwards beginning with the individual quadrats and combining and recombining them to form successively more inclusive groups. The process of classification can be accomplished by the use of either monothetic or polythetic criteria. In a monothetic classification two "sister" groups are distinguished by the presence in one and the absence in the other of a single attribute. For instance by the possession of a particular species in one group and its absence in the other. In a polythetic classification, however, overall similarity is used based on all the attributes (Krebs, 1989). For instance based on some aspects of all species.

In general, any procedure in vegetation classification involves an arrangement of communities (or more precisely, abstraction from stand data) into classes members of each class have in common a constellation of attributes (species), which serve to set them apart from members of another class. Implicit in this approach is the suggestion that there is some discontinuity in species (attribute) composition between the concrete samples of vegetation in the field and theoretical units abstracted from such field data.

Ordination

In contrast to classification, the concept of ordination is based on the premise that there are no such discontinuities in natural vegetation except where there may be discontinuities in the physical environment. It is a method for arranging species and samples along one to many dimensions so that similar species or samples are close together and dissimilar species or samples are far apart. Ordination summarizes community data of many species and many samples by collapsing the data onto a single graph, which shows the pattern in them. Since ordination scores all community data on a continuous scale, it does not produce a classification of community types. It is useful for recognizing the pattern present in a community data (Krebs, 1989).

Hierarchical system of classification has been used extensively for plant community studies at different ecosystems. For instance, Gittins (1965), Gimingham et al. (1966), Harrison (1970), and Ward (1970) had applied this technique for temperate vegetations.

Greig-Smith et al. (1967), Kershaw (1968), applied it to tropical vegetation. Zerihun Woldu (1980), Sebsebe Demissew (1980), Hailu Sharew (1982), Lisanework Negatu (1987) and Tamrat Bekele (1994) have used this technique in classifying vegetation they studied in Ethiopia.

2. Objectives of the study

The study is conducted with the following objectives:

- To document the species composition and describe the plant community types of Choke Mountain
- To identify the species composition and community changes along altitudinal gradient
- To relate some environmental factors vis-à-vis species distribution.

3. Description of the study area

3.1 Location

The study was carried out on Choke Mountain. It is a range of mountains with elevation generally above 3000 m. Some of the peaks reach above 4000 m (for example 4020 at a point called Aba Demo). This mountain is 56 km north of Debre Markos. It is located roughly between 10^0 37' and 10^0 45' N, and 37^0 45' and 37^0 53' E. The total area covered by these mountains estimated to be 215 km^2.

3.2 Geology

The Geology of the study area is of volconics of tertiary era known as the trap series that overlay the Mesozoic sedimentary rocks. According to Mohr (1971) Olivine basalts, often amygdaloidal (with agate and zeolite), are reported to be overlain by basalts and silicic lavas. The silicic lavas include trachyte and rhyolite.

3.3 Soil

Inorganic component of soil on Choke Mountain appears to be derived from the weathering of rocks of silicic lavas of trachyte and rhyolite. The soil is often shallow (10-20 cm), even though rich in undecomposed organic matter.

At the lower part of the mountain, the soil is relatively thicker than the upper slopes. At the upper part of the mountain, the soil is so shallow that it was difficult to auger below the depth of 30 cm. Compared to the upper slopes, soils at valleys and flat bottoms of the mountain are also relatively fine textured and moister and dark colored.

3.4 Climate

The climate of high African mountains is fundamentally governed by two geographical factors: the vicinity to the equator and the high altitude above sea level (Hedberg, 1964).

The exact climatic pattern could not be described fully because of lack of meteorological data of the study area. However, temperature and rainfall from Debre Markos, which is 56 km away, and 2575 m high are used to relate the climatic conditions of the study area.

3.4.1 Temperature

In the afroalpine belt, seasonal variations in temperature are less important than diurnal ones. There is always "summer every day and winter every night" (Hedberg, 1964). In at least the major part of this belt, frost occurs on many if not most nights of the year, whereas day temperatures are not so cold. Daniel (1988) made a comparative study on climatic patterns of Bale and Simen mountains. According to him, frost can be very common in the mountainous regions of Ethiopia so much that most of the areas above 3000 m may experience severe frost (up to -10 ^{0}c at ground level) and some areas at elevations between 2000 and 3000 m may experience light to medium frost (0 to -5^{0}c at ground level).

Although not actually measured, this phenomenon also holds true to Choke Mountain. This has been evidenced from the observation during field studies of frost covering the ground during mornings.

As observed from temperature data (see table 1), Debre Markos, which is 2575 m high above sea level, has got mean annual temperature of 16.3^{0}c. According to Lind and Morison (1974), for each 300 m increase in altitude there is a 1.6 ^{0}c fall in temperature. Based on this fact, the mean annual temperature of the study area at the foot (3500 m) and peak of the mountain (4020 m) will be 11.36^{0}c and 8.59^{0}c respectively.

Table 1: - Mean monthly Max. and Min. Temperature data (in ^{0}c) of Debre Markos meteorological station recorded over 17 years.

Month	Jan	Feb	Mar	Ap	May	June	July	Aug	Sep	Oct	Nov	Dec	Average
Mean Monthly Max.	23.9	24.8	25.5	25.2	24.1	20.5	18.6	18.7	20.3	31.6	22.7	23.2	22.43
Mean Monthly Min.	8.5	9.8	11.2	11.8	11.7	10.7	10.6	10.6	10.0	9.6	8.7	8.5	10.14

From National Meteorological Service Agency, Addis Ababa.

3.4.2 Rainfall

The highlands of Gojam are characterized by one rainy season and one dry season (Daniel, 1977). There are seven rainy months from April to October. Small rains are in April and October i.e., at the beginning and the end of the rainy season. The big rains are from May to September with high concentration of rainfall in July, August, and September.

Rainfall data from the study area was not available. However, data obtained from Debre Markos can be used to help the estimation of rainfall taking into consideration the modification of rainfall distribution by altitude. In general, highlands, which rise to over 2500 m, receive between 1400 and 1800 mm of annual rainfall. Those, which lie between 600 and 2500 m, receive between 1000 and 1400 mm of annual rainfall (Daniel, 1977). From rainfall data (see table 2). Debre Markos with altitude of 2575 m receives about 1317.5 mm annual rainfall. From this, the study area, which lies above 2500 m, is assumed to have annual rainfall between 1400-1800 mm. As explained by Hedberg (1964) explained that at altitudes above 4000 m, precipitation often occurs in the form of snow and hail that can not be measured by rain gauges. Therefore, the actual value that can be measured at higher points (near 4000 m) may be less.

Table 2: - Mean monthly rainfall data of Debre Markos meteorological station that recorded over 17 years.

Month	Jan	Feb	Mar	Ap	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual R.f
Mean Monthly R.f	18.9	13.7	39.9	68.5	110	162	269	31	199	79	24.3	20	1317.5 mm

(From Meteorological Service Agency, Addis Ababa).

3.5 Vegetation

Vegetation is the total plant cover of a region, area or place. It is made up of one or more plant communities or aggregation of plants. The type of plant species that make communities and hence vegetation type of an area is governed by environmental factors such as climate and soil.

The vegetation of Ethiopia is extremely complex. This arises from the great variations in altitude implying equally great spatial and temporal differences in moisture and condition for drainage as well as temperature all within short distances.

Several authors have attempted to classify the vegetation of Ethiopia on physiognomic basis. The most comprehensive scheme is that of Pichi-Sermolli (1957). He recognized 23 vegetation types. However, at present nine vegetation groups are recognized (Conservation Strategy of Ethiopia, 1997).

High Mountain vegetation is one of the nine major vegetation categories of Ethiopia. In East Africa as a whole, this has been named as afroalpine vegetation by Hauman (1933,1955) as cited in Lind and Morison, 1974.

The afroalpine regions, which on the average are higher than 3200 m, are the slopes and tops of the highest mountains (Tewolde, 1988). Choke Mountain is one of these regions with distinctive vegetation types from its surrounding lowland areas. It consists of five life forms, which are described by Hedberg (1964). These are giant rosette plants,

tussock grasses, acaulescent rosette plants, cushion plants and sclerophyllous shrubs (see fig.1).

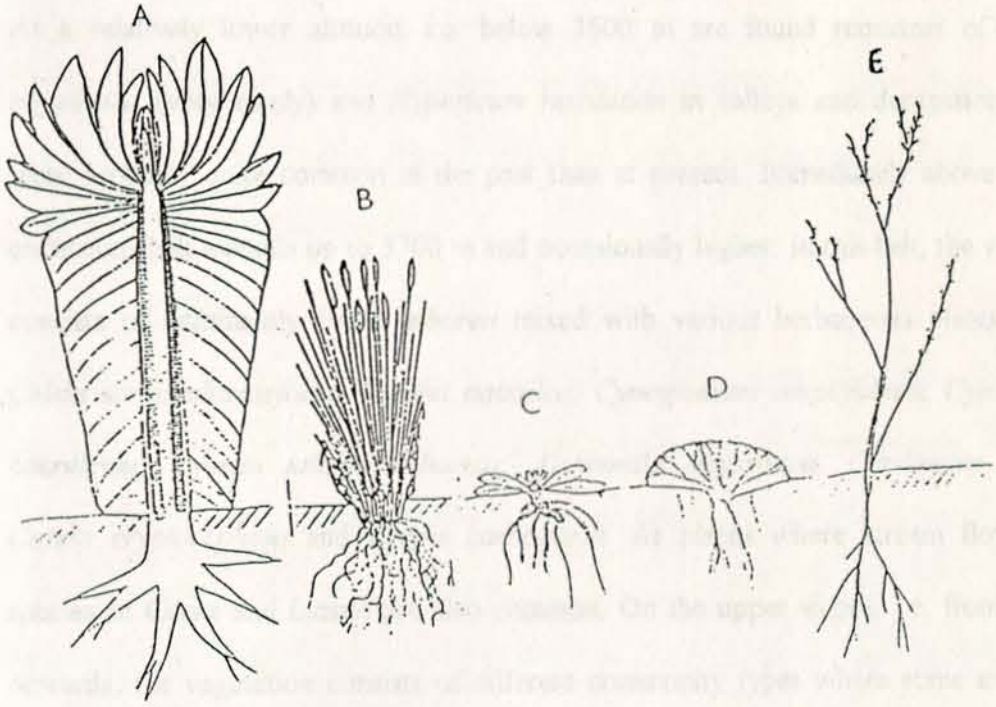

Fig.1 Diagrammatic drawings of the five phanerogamic life-forms of the afroalpine belt. A. giant rosette plant; B. tussock grasses; C. acaulescent rosette plant; D. cushion plant; E. sclerophyllous shrub. (From Hedberg, 1964.)

Hedberg (1957) attempted to define the altitudinal distribution of African mountain vegetation in terms of belts. His scheme is based mainly on the physiognomy of vegetation using dominant plant communities. He identified three vegetation belts, namely the upland forest belt, ericaceous belt and the alpine belt. Vegetation on Choke Mountain conforms to this scheme.

At a relatively lower altitude, i.e. below 3600 m are found remnants of *Hagenia abyssinica* (very rarely) and *Hypericum revolutum* in valleys and depressions, which were probably quite common in the past than at present. Immediately above this, the ericaceous belt extends up to 3700 m and occasionally higher. In this belt, the vegetation consists of dominantly *Erica arborea* mixed with various herbaceous plants such as *Celsia scrophulariaefolia, Mentha aquatica, Cynoglossum amplifolium, Cynoglossum coeruleum, Swertia kilimandscharica, Alchemilla abyssinica, Cardamine obliqua, Cotula cryptocephala* and *Crepis carbonaria*. At places where stream flows some species of *Carex* and *Luzula* are also common. On the upper slopes, i.e. from 3700 m onwards, the vegetation consists of different community types where some exist in all directions to cover an extensive area and others restricted to occupy certain micro sites in patches. In any case, area above 3700 m is dominantly covered by plant species such as *Kniphofia foliosa, Lobelia rhyncopetalum, Euryops pinifolius, Helichrysum citrispinum* mixed with various grasses and other herbaceous plant species.

On rocky outcrops and crevices of this belt are also seen growing plants such as *Portulaca quadrifida, Silene macrosolen, Helichrysum splendidum*, together with various mosses and lichens.

3.6 Population and Land use

Choke Mountain has a comparatively low human population, owing to the extreme climatic conditions at higher altitude, which relatively result in low productivity of the crops and grassland plant species.

The study area is being administered by different Woredas whose centers are far and inaccessible to get information on human population and livestock density. However, due to extreme climatic conditions at higher altitudes that result in low productivity of crop and grassland plant species, human population is expected to be low compared to the surrounding lowlands.

An all weather road that crosses the mountain and link Debre Markos to Digo Tsyion (a small town 20 km north of the mountain) was constructed recently (in 1997). This contributed much to easy crossing of the mountain and increment of the population in the surrounding areas. From observations during field studies of newly established villages (4 to 5 years old), and information gathered from the inhabitants, human

population in the area has been increasing in association with the construction of the road.

Barley, bean and potato are commonly grown in the area. Animal husbandry is common and sheep cattle and horses are common on this mountainous area.

4.Materials and Method

4.1 Vegetation data

Vegetation data were obtained from 60 sample plots of size 10 x 10 m. Sample plots were systematically taken every 50 m interval from along the transects laid at different sites (see fig. 2). In each sample plot, all vascular plant species were registered and for each percent cover was estimated and later converted to 1-9 scale of van der Maarel (1979) (see table 3). Specimens were collected, pressed, dried and identified in the National Herbarium at Addis Ababa University.

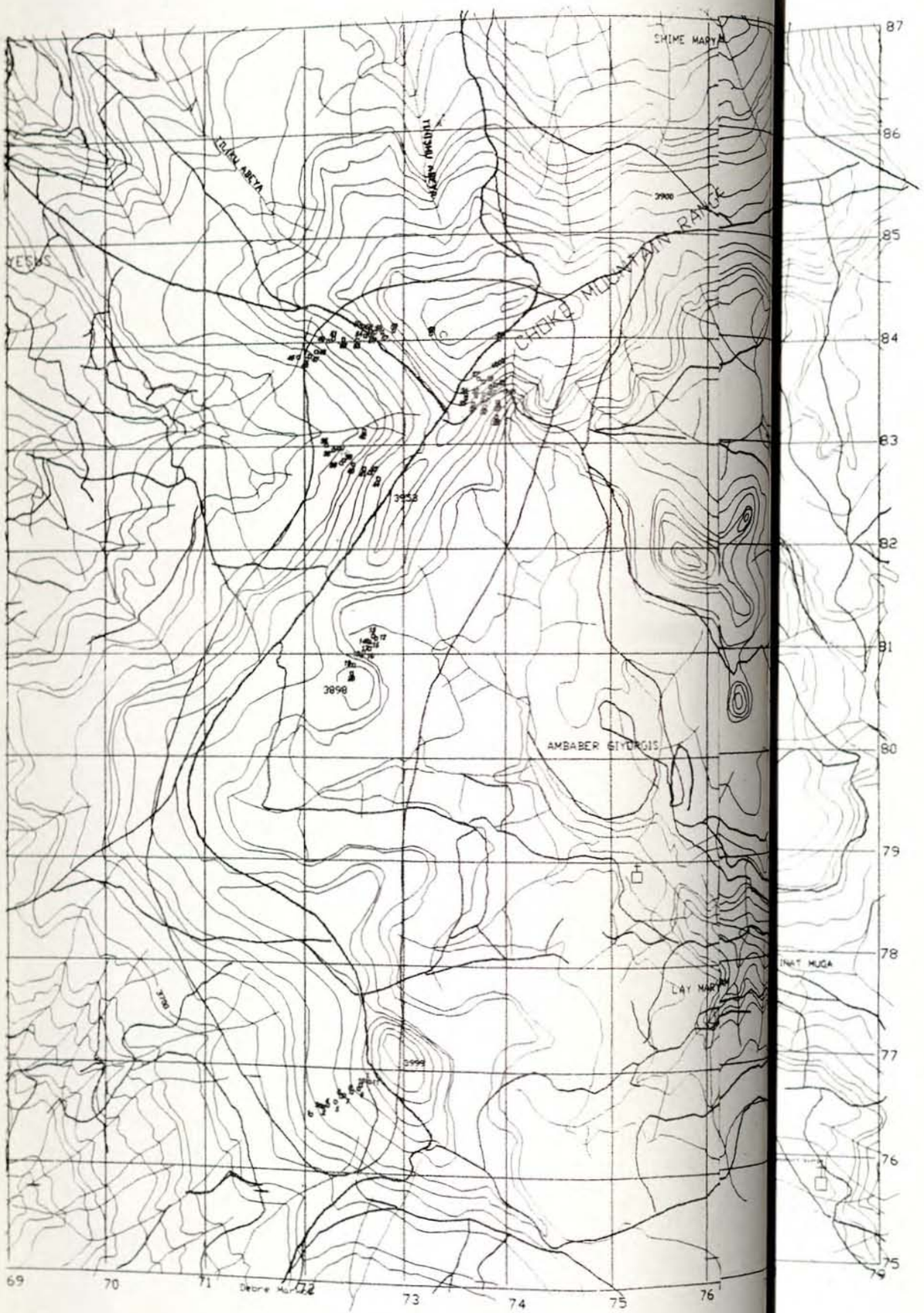

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Fig. 2 Map showing the distribution of sample plots in the study area

Table: 3 Percent cover transformation of van der Maarel (1979).

Percent cover	Transformed value
Rare	1
0-3	2
3-5	3
5-9	4
9-19	5
19-38	6
38-63	7
63-88	8
>88	9

4.2 Environmental data

4.2.1 Soil sampling and analysis

Soil samples were systematically taken from the center of each sample plots using an auger at depths of 0-10 cm and 20-30 cm. The samples were collected in polythene bags, brought to the laboratory and air dried for chemical and physical analyses in soil laboratory at Addis Ababa University.

A Chemical analysis

4.2.1.1 Determination of soil pH

The pH was determined using Beckman φ .12 pH/ISE pH meter in 1:1 soil/water ratio. The soil sample was first made to pass through a 2 mm sieve. Twenty gram of soil and twenty ml of distilled water were mixed in a 50 ml beaker, and allowed to stand for 30 minutes while being stirred occasionally with a glass rod. After 30 minutes, the electrode of the pH meter was inserted to measure the pH.

4.2.1.2 Determination of soluble salts

Soil soluble salts were determined by conductivity determination method of Chopra and Kanwar (1982) in which 1:2 soil water suspension was employed. A 50 gram of air dried soil (that sieved through 2 mm sieve) was mixed with 100 ml of distilled water in a conical flask, stirred with glass rod to mix well and shaken for about 18 to 20 hrs on orbital shaker. The suspension was filtered under suction using Buchner funnel fitted with a 15 cm Watman no.1 filter paper. After rinsing the conductivity cell with distilled water and test solution, it was immersed in the test solution and conductivity reading was taken using CRISON CDTM-523 conductivity meter.

4.2.1.3 Determination of Organic Carbon

Walkley-Black titration method indicated by Juo (1978) was applied. To a 0.5g of air-dried soil (that sieved through 0.5 mm sieve), 10 ml of Potassium dichromate (1N K_2 Cr_2 O_7) and 20 ml of conc. Sulphuric acid (H_2 SO_4) were added. The mixture was shaken by hand for one minute and allowed to stand for 30 minutes. After 30 minutes, 100 ml of distilled water, 10 ml of 0-phosphoric acid (85%) and 1ml of Diphenylamine indicator solution were added. Finally the dichromate (Cr_2 O^{-2}_7) that was not reduced by soil organic matter was titrated with 0.5 N of Ferrous sulphate solution till the violet color was changed to green.

Percent organic carbon and organic matter were calculated as follows.

$$\% \text{ Organic Carbon} = \frac{\text{mill equivalent } K_2Cr_2O_7 - \text{mill equivalent } FeSo_4.7H_2O \times 0.003 \times 100}{\text{gm of air - dry soil}}$$

% Organic matter = % Org. C x 1.724

4.2.1.4 Determination of available phosphorus

Available phosphorus was determined following Bray No 1 method as indicated in Juo (1978). To 1 gram of air-dried soil (that sieved through a 2 mm sieve) in the 15 ml of centrifuge tube, 7 ml of extracting solution (made by mixing 15 ml of 1 N ammonium fluoride (NH_4 F) and 25 ml of 0.5 N Hydrochloric acid (HCl) with 460 ml of distilled water) was added. The mixture was shaken for 1 minute on a mechanical shaker and centrifuged at 2,000 round per minute (r.p.m) for 15 minutes. Two ml of the clear supernatant was pipetted into a 20 ml test tube and 5 ml of distilled water and 2 ml of ammonium molybdate solution $(NH_4)_6 MO_7 O_{24}.4H_2O$) were added. After proper mixing, 1 ml of dilute stannous chloride ($Sn Cl_2.2H_2O$) solution was added and mixed again. Five minutes later but not exceeding 20 minutes, percentage transmittance was measured at 660 NM with MILTON ROY spectronic 1001 spectrophotometer. The concentration of phosphorus corresponding to the transmittance was then obtained from calibration curve made from standard phosphorus concentrations. The amount of extractable phosphorus in soil is calculated using the following formula.

Content of extractable phosphorus in soil = ppm of extract solution x 35

4.2.1.5 Determination of total Nitrogen

Percent nitrogen was determined by Kjeldahl method that involves the digestion in tecator 1015 digester and steam distillation processes in tecator Kjeltic system 1002 distilling unit following the procedure indicated by Juo (1978). One gram of soil that sieved through 0.5 mm sieve was put in digestion tubes. Seven gram of potassium sulphate ($K_2 SO_4$) and 0.8 g of copper sulphate ($Cu SO_4$) were then added to the tubes. After adding 12 ml of concentrated sulphuric acid ($H_2 SO_4$), the mixture was gently shaken to wet the sample with acid. The digestion tubes in the rack (with exhaust system fitted) were loaded into the digestion block that was preheated to 420^0c. Digestion was carried out for about an hour until all samples became clear with blue/green solution. After the completion of the digestion process, the rack of tubes with exhaust still in place were removed from the digestion block and cooled for 10-20 minutes. This was followed by the addition of 75 ml of deionized water and 50 ml of 40% Sodium hydroxide (NaOH) into each tube. Steam distillation was ran for 4 minutes. The distillate was collected in conical flask containing 25 ml of receiver solution (Boric acid indicator solution) where the color of the receiver solution changed to green indicating the presence of alkali-ammonia. The distillate was titrated with standard hydrochloric acid (0.2N) until blue/grey end point is achieved. A blank was ran by using the same chemicals and following similar steps.

Calculation of results

$$\% N = \frac{(T - B) \times N \times 14.007 \times 100}{\text{weight of sample in mg.}}$$

Where:

T = Titration volume for sample

B= Titration volume for blank

N = Normality of acid to four decimal places

4.2.1.6 Determination of exchangeable potassium and sodium

Exchangeable potassium and sodium were determined photometricaly following the procedure given by Juo (1978) in which ammonium acetate (1N NH_4 OAC at, pH = 7.00) was used as an extraction solution.

To a 5 gm of air-dried soil sample (sieved through 2 mm sieve), 30 ml of extracting solution was added and then shaken on a mechanical shaker for 2 hours. The suspension was centrifuged (2000 round per minute) for 5 to 10 minutes. The clear supernatant was decanted into 100 ml volumetric flask. Another 30 ml of extracting solution was added to the sample and shaken for 30 minutes, centrifuged and the supernatant decanted into the same volumetric flask. This step was repeated once more and the volume of the clear supernatant made up to the mark with Ammonium acetate. Exchangeable K^+ and Na^+ are determined by flame photometer.

Standard curves were produced by the use of 0, 25, 50, and 75, 100 ppm. standard series of both K^+ and Na^+. The concentrations of K^+ and Na^+ in the soil solutions corresponding to readings from flame photometer were then found from these curves.

B Physical analysis

4.2.1.7 Hydrometer method of mechanical analysis

Hydrometer method of mechanical analysis was done following the procedure of Juo (1978). To 51 gm of air-dried soil (sieved through 2 mm sieve) in the 250 ml beaker, 50 ml of 5% sodium hexametaphosphate was added along with 100 ml of distilled water. This was mixed with stirring rod and let to stand for 30 minutes. After stirring for 15 minutes by the use of multimix machine, the soil suspension was transferred into 1000 ml graduated cylinder. The suspension was diluted by adding distilled water to the volume. Covering the top with hand, the cylinder was inverted several times until all the soil is in the suspension. The cylinder was then put on a table and 40 seconds later soil hydrometer was placed by sliding slowly into the suspension until the hydrometer was floating. The first hydrometer reading and temperature were taken after 40 seconds. Three hours after the first hydrometer reading, the second hydrometer reading and temperature were again recorded.

Percent sand, clay and silt were found by the use of the following formulae

$$\% \text{ Sand} = 100 - [H_1 + 0.2 (T - 68) - 2] 2$$

$$\% \text{ Clay} = H_2 + [0.2 (T_2 - 68) - 2]2$$

$$\% \text{ Silt} = 100 - (\% \text{ sand} + \% \text{ clay})$$

H_1 = Hydrometer reading at 40 seconds

H_2 = Hydrometer reading after 3 hours of the first reading

T_1 = Temperature reading at 40 seconds

T_2 = Temperature reading 3 hours after the first reading

4.2.1.8 Other environmental variables

Other environmental variables such as, slope, altitude and position were also recorded by the use of Brunton clinometer, Everst altimeter and Garmin G.P.S respectively. Degree of disturbances in each sample plot was also observed to help determine the extent of burning, cutting and grazing. Accordingly ordinal numbers between 1 and 5 where 1= with no disturbance, 2 = less disturbed, 3 = disturbed, 4 = very disturbed and 5 = with extreme disturbance were assigned.

5. Data analysis

A. Vegetation

For the classification purpose, the converted values, which correspond to the percent cover of each species in the community, were used to measure dissimilarity between sample plots by distance optimization. Sample plots were then clustered using computer package SYNTAX (Podani, 1988) following average linkage clustering. Diversity index was computed using the Shannon-Weaver function given by (Krebs, 1989) as: -

$$H^1 = - \text{Sum of } (p_i)\ (\ln p_i)$$

Where:

H^1 = index of species diversity

P_i = proportion of the total sample belonging to ith species.

B. Environmental variables

All the environmental variables were averaged for each community. To examine whether the differences between these mean environmental variables are significant or not, Analysis of Variance (ANOVA) at a probability of *0.05* significance level was done.

6. Result and discussion

From the sample plots clustered at a dissimilarity level between 0.3 and 0.5, five major plant communities were found to represent the vegetation of the study area. These communities were designated by letters on a dendrogram (see fig 3) to which corresponding names were given by a combination of two or more species with relatively high percent cover value. Sample plot 60 on a dendrogram was found quite dissimilar from the rest of sample plots. It could have been considered as independent community if additional sample plots had sampled.

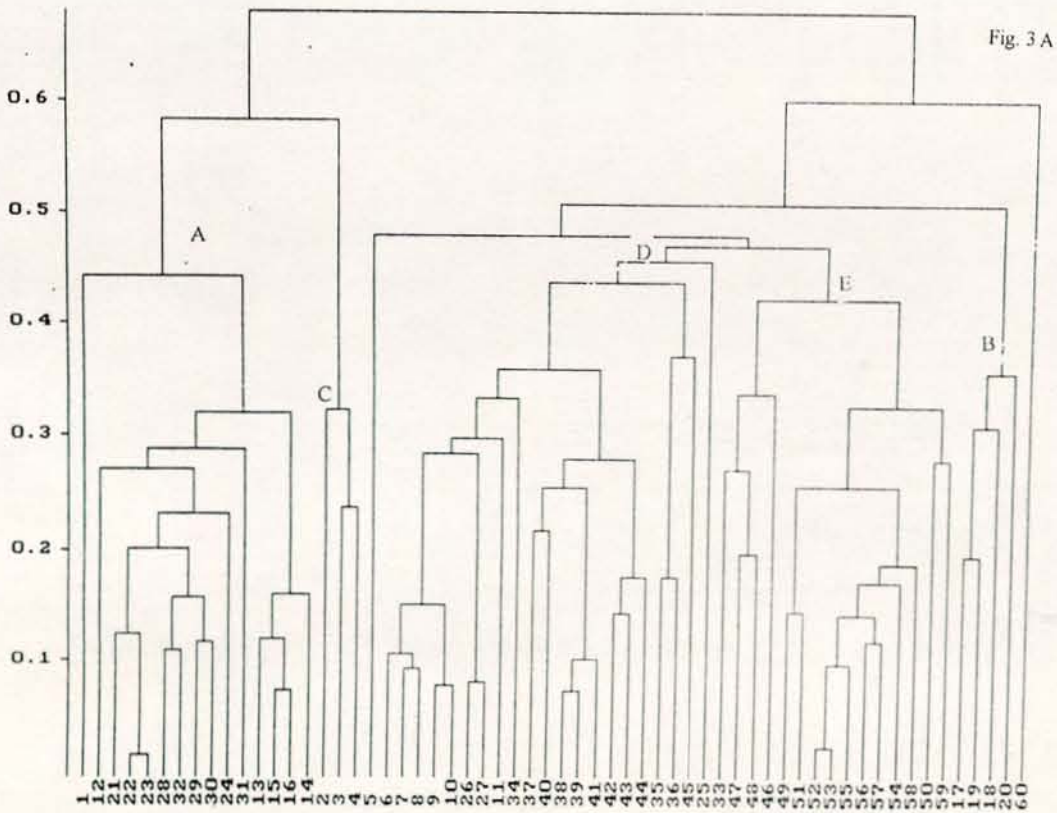

Fig. 3 A dendrogram showing the five communities of study acra.

Average percent cover of each species, belonging to each community was summarized in table 4. From the table it can be observed that some of the species (those in blocks) are more or less restricted to either of the five communities. Among these, some serve to distinguish sample plots into groups that agree with a dendrogram produced above.

Table 4 Summary of percent cover value of each species in the communities

	A	C	B	D	E
Lobelia rhyncopetalum	0.40	0.67	1.60	4.13	4.87
Kniphofia foliosa	2.93	1.33	7.00	5.90	4.43
Cerastium octandrum	1.46	2.00	2.00	2.13	2.06
Sagina abyssinica	0.13	1.25	2.00	2.73	3.12
Cotula cryptocephala	1.07	3.67	0.50	2.00	2.06
Carduus nyassanus	0.53	0.63	2.50	1.18	0.87
Haplocarpha rueppellii	1.67	7.00	1.50	2.00	2.06
Crepis carbonaria	0.40	1.33	1.50	1.36	0.87
Arabis thaliana	0.40	1.33	1.50	1.36	0.87
Trifolium acaule	4.73	4.00	4.50	6.32	6.37
Satureja pseudosimensis	1.20	1.33	2.00	1.36	1.75
Festuca abyssinica	0.80	2.00	2.00	1.00	0.50
Deschampsia flexuosa	0.67	2.00	2.00	0.55	0.12
Romulea fischeri	0.53	0.67	1.00	0.27	0.62
Alchemilla abyssinica	8.47	6.33	6.75	4.00	5.68
Galium hochestetteri	1.87	1.33	1.50	0.36	0.37
Hagenia abyssinca	0.34	0.00	0.00	0.00	0.00
Hypericum revolutum	1.37	0.00	0.00	0.00	0.00
Erica arborea	8.07	0.00	0.00	0.00	0.00
Helichrysum formosissimum	0.40	0.00	0.00	0.00	0.00
Rumex nepalensis	1.33	0.00	0.00	0.00	0.00
Conyza variegata	0.13	0.00	0.00	0.00	0.00
Senecio ochrocarpus	0.13	0.00	0.00	0.00	0.00
Agrocaris melanatha	0.67	0.00	0.00	0.00	0.00
Celsia scrophulariaefolia	0.01	0.00	0.00	0.00	0.00
Cineraria deltoidea	0.67	0.00	0.00	0.00	0.00
Anthriscus sylvestris	0.27	0.67	0.00	0.00	0.00
Apium graveolens	0.40	0.67	0.00	0.00	0.00
Helichrysum nudiflora	0.13	0.67	0.00	0.00	0.00
Anthemis tigreensis	0.13	0.13	0.00	0.00	0.00
Cardamine obliqua	0.13	0.67	0.00	0.00	0.00
Cardamine hirusta	0.40	1.33	0.00	0.00	0.00
Mentha aquatica	0.13	0.67	0.00	0.00	0.00
Bromus leptoclados	0.80	2.00	0.00	0.00	0.00
Carex erythrorrhiza	0.13	1.33	0.00	0.00	0.00
Cynoglossum coeruleum	0.67	0.27	0.00	0.00	0.00
Drymaria cordata	0.13	1.33	0.00	0.00	0.00
Agrostis viridis	0.13	1.33	0.50	0.00	0.00
Cynoglossum amplifolium	0.00	1.33	0.50	0.00	0.00
Senecio schultzii	0.00	0.67	0.00	0.00	0.00
Senecio myriocephalus	0.00	1.33	0.00	0.00	0.00
Carex monostachya	0.00	7.67	0.00	0.00	0.00
Salvia nilotica	0.00	0.67	0.00	0.00	0.00
Poa leptoclada	1.80	1.68	0.00	1.62	0.00
Barstia decurva	0.00	0.00	0.50	0.00	0.00
Swertia crassiuscula	0.40	0.00	1.00	0.00	0.00
Swertia kilimandscharica	0.13	0.00	1.00	0.00	0.00
Senecio nanus	0.00	0.00	0.50	1.09	2.25
Portulaca quadrifida	0.00	0.00	0.00	0.01	0.00
Silene macrosolen	0.00	0.00	0.50	0.12	0.00
Sagina afroalpina	0.00	0.00	0.00	0.25	0.00
Euryops pinifolius	0.13	0.00	4.50	3.31	1.87
Luzula abyssinica	0.80	2.00	0.00	0.27	0.67
Poa annua	0.93	0.00	0.00	1.72	1.62
Alchemilla microbetula	0.00	0.00	0.00	6.23	0.37
Echinops giganteus	0.00	0.00	0.00	0.18	0.13
Helichrysum splendidum	0.00	0.00	0.00	0.00	0.12
Aira caryophyllea	0.00	0.00	0.00	0.00	0.32
Carduus chaemeocephalus	0.00	0.00	0.00	0.00	0.12
Arabis alpina	0.00	0.00	0.00	0.00	0.12
Agrostis quinqueseta	0.00	0.00	0.00	0.00	0.47
Helichrysum gofense	0.00	0.00	0.00	0.00	0.12
Senecio farinaceus	0.00	0.00	0.00	0.00	0.12
Helichrysum citrispinum					2.93

In the following part of this chapter, short description will be given for each community type.

A. ***Erica arborea-Alchemilla abyssinica-Trifolium acaule*** **Type**

Fig.4 represents community A in part. The ericaceous belt, which in this study represented by "*Erica arborea-Alchemilla abyssinica-Trifolium acaule*" community, was found to occur at the lower parts of the Choke Mountain. *Erica arborea, Alchemilla abyssinica and Trifolium acaule* were found as the dominant species of this community. While *Alchemilla abyssinica* and *Trifolium acaule* cover the field layer, *Erica arborea*, which is a characteristic species of this community, forms the upper layer. It normally found below 3700 m and occasionally between 3700 and 3800 m where it appears in a sparse and stunt sature interspaced with some individuals of *Kniphofia foliosa* and/or *Lobelia rhyncopetalum, Carddus nyassanus, Euryops pinifolius.*

Fig. 4. Picture to show *Erica arborea-Alchemilla abyssinica-Trifolium acaule* community in part.

B. *Kniphofia foliosa-Alchemilla abyssinica-Euryops pinifolius* Type

This community is one of the communities occurring in the form of patches interrupting the continuous distribution of the *Lobelia-Kniphofia* community. *Kniphofia foliosa Alchemilla abyssinica* and *Euryops pinifolius* are the dominant species of this community forming the upper layer.

C. *Carex monostachya-Haplocarpha rueppellii* Type

Carex monostachya-Haplocarpha rueppellii community is one of the principal communities that occur just at the upper part of the ericaceous belt at level to gentle sloping places . This community was found on soils of relatively high water content. *Carex monostachya* that forms a dense tussock (see fig. 5) is a characteristic and dominant species of this community. The commonest sub-dominant species of this community were *Haplocarpha rueppellii* and *Alchemilla abyssinica* that spread between the tussocks of *Carex monostachya.*

Fig.5 Picture showing patches of tussock grasses.

D. *Lobelia rhyncopetalum–Kniphofia foliosa, Trifolium* *acaule-Alchemilla microbetula* Type

This community is partly represented as fig. 6. It occurs continuously distributed in all parts of the mountain mainly on moderately steep slopes rich in undecomposed organic matter that resulted largely from the accumulation of dead leaves and stems of *Kniphofia foliosa* and *Lobelia rhyncopetalum. Lobelia rhyncopetalum, Kniphofia foliosa, Trifolium acaule* and *Alchemilla microbetula* are the dominant species of this community.

Fig. 6 picture showing *Lobelia rhyncopetalum-Kniphofia foliosa, Trifolium acaule- Alchemilla microbetula* **Community.**

E. *Trifolium acaule-Lobelia rhyncopetalum, Alchemilla abyssinicca-Knifphofia foliosa*. Type

This community is one of the most important plant communities of this mountain that extends in patches up to the higher part of the alpine belt. It occurs on moderately to steeply sloping, comparatively dry, stony ridges and rocky ground. At places the ground becomes very open with much bare ground between the rocks. *Helichrysum citrispinum* is the characteristic species of this community growing on open field in cushion form (see fig.7). Some times it occurs interspaced with some individuals of *Lobelia rhyncopetalum, Kniphofia foliosa, Euryops pinifolius, Carduus nyssanus* growing above the cushions of *Helichrysum citrispinum*.

Fig. 7 picture showing *Trifolium acaule-Lobelia rhyncopetalum*,-*Alchemilla abyssinica-Kniphofia foliosa* **Community**

Table 5: Species richness and diversity of each community.

Community	Species No.	Species diversity ($H^1 = -\Sigma(P_i)(\ln p_i)$
A	44	3.0
B	24	2.8
C	36	3.24
D	26	2.95
E	30	2.95

Values of species richness and diversity of each community is given in table 5. Community 'A' with the lowest altitude was found to be rich in species compared to the rest of communities at higher altitudes. According to Hedberg (1964) and Tewolde-Berhan Gebregziaber (1988), soil temperature and moisture are better at the lower elevations of High Mountain for plant growth. These conditions fovoured community with high species number in lower altitude of the study area. Values of diversity index

showed that, all communities have more or less the same diversity showing that species are equally frequent within their respective communities.

Comparisons of communities based on statistical treatment of environmental variables.

Results of soil analysis and other measured environmental factors are averaged for each community and given in table 6 below. From statistical treatment of these environmental variables, differences among communities in values of pH, organic matter, available phosphorus, electrical conductivity, and exchangeable sodium were insignificant. However, values of total nitrogen, exchangeable potassium and soil particle fractions showed significant difference at $p < 0.05$

Altitude which influences the gradation of environmental variables such as rainfall (moisture), temperature, atmospheric pressure and radiation intensity also showed significant differences between the communities at $P<0.05$. It appears one of the principal factors to determine vegetation structure, species composition and distribution in the study area.

Measurements of slope also vary significantly among the five communities ($P<0.05$). Slope affects vegetation through its influence on the thickness as well as nutrient and water content of the soil.

Human disturbances such as cutting and burning as well as livestock grazing and trampling found to affect the distribution of plant species. Directions that are proximal and easily accessible to human settlement were found to be disturbed highly. These areas support plant species that are not eaten by livestock, easily burned or taken by people for various household purposes.

Table 6. Average values of the Measured Environmental Factors for each Community

Community	% Sand		% Silt		%Clay		%O. M		E.C		A.P		PH	
	UL	**LL**	UL	LL	UL	LL	UL	LL	UL	LL	UL	LL	UL	LL
A	76.6	65.4	13.6	33.6	4.70	0.98	22.3	18.6	O.42	0.3	2.1	2.5	4.08	3.98
B	88.1	63.2	9.03	35.6	2.87	1.11	22.2	19.5	0.52	0.39	1.63	1.88	4.12	4.14
C	71.33	60.67	14.73	36.06	13.94	3.27	21.86	20.04	0.57	0.29	1.27	0.83	4.24	4.28
D	81.67	57.44	16.54	40.78	1.79	1.78	23.36	17.23	0.51	0.32	2.02	1.84	4.27	4.07
E	77.82	52.28	19.73	45.40	2.45	2.32	23.3	16.63	0.42	0.32	1.28	2.13	4.3	4.37

Table 6: - Continued

			Exchangeable bases (meq/100g soil)						
Community	%TN		Na^+		K^+		Altitude (m)	Slope	Degree of disturbance
	UL	LL	UL	LL	UL	LL			
A	0.72	0.09	0.14	0.20	0.38	0.34	3715	27.2	2.3
B	1.24	0.25	0.09	0.15	0.32	0.18	3770	29.5	2.5
C	0.25	0.02	0.09	0.22	0.10	0.16	3790	13	2.33
D	0.41	0.02	0.14	0.17	0.29	0.23	3820	18.8	3.00
E	0.18	0.09	0.12	0.21	0.44	0.32	3850	14.14	2.2

UL= Upper layer, 0-10 cm

LL = Lower layer, 20-30 cm deep

OM = Organic matter

EC = Electrical conductivity in (millisimens/cm)

AP = Available phosphorus (ppm) TN = Total nitrogen

7. Conclusion

From the sixty sample plots taken for the investigation of vegetation, sixty-four different plant species have been recorded. Cluster analysis of these sample plots resulted in five major plant groups (communities). In ascending order of altitude, these comminutes are *Erica arborea-Alchemilla abyssinica-Trifolium acaule, Kniphofia foliosa-Alchemilla abyssynica-Euryops pinifolius, Carex monostachya-Haplocarpha rueppellii Lobelia rhyncopetalum-Kniphofia foliosa-Trifolium acaule* and *Trifolium acaule-Lobelia rhyncopetalum, Alchemilla abyssinica-Kniphofia foliosa*. Variations in altitude, total nitrogen, exchangeable potassium and proportions of soil particle fraction were found to determine species distribution and community differentiation. Variations in slope and extent of

interference by human being and livestock also contributed to the community differentiation.

8. Recommendation

More than 85% of the Ethiopian population lives in rural areas depending on agriculture for their livelihood. Their activities directly interfere with the natural ecosystem. While human population grows at a faster rate, agricultural out put show very less increment and unable to feed the growing population. The increased demand for land would force farmers to move to marginal lands which in turn aggravates the land degradation, loss of biodiversity and deterioration of the natural environment in general.

The study area comprises the sub-afroolpine and afroolpine ecosystems that consist of endemic plant species such as *Lobelia rhyncopetalum* and *Kniphofia foliosa* that are restricted to these areas or less distributed in other ecosystems of the country. According to Mesfin (1991) these ecosystems are an important center of endemism for many plant taxa. However indiscriminate cutting and burning of these vegetations and change of the natural land cover and land use would lead to the loss of these endemic species.

Vulnerability to soil erosion due to steep topography of this area results in degradation of the land if the area is devoid of its vegetation cover. Therefore, to protect vegetation from destruction, relevant management plan should be designed

and the local people should be thought of the concept and importance of conservation to protect vegetation. Further study should also be carried in the area and in other neighbouring mountains to have a clear picture of the afroalpine vegetation of northern part of the country to design appropriate conservation strategy.

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Appendix-1

Plant species recorded from the study site

Collection No (In Meseret Chimdessa)	Scientific name	Family name
1	*Hagenia abyssinica* (Bruce) J. F. Gmel.	Rosaceae
2	*Hypericum revolutum* Vahl	Hypericaceae
3	Erica arborea L.	Ericaceae
4	*Lobelia rhncopetalum* (Hochst.) Hemsl.	Lobeliaceae
5	*Kniphofia foliosa* Hochst.	Asphodelaceae
6	*Euryops pinifolius* A. Rich.	Asteraceae
7	*Portulaca quadrifida* L.	Portulaccaceae
8	*Silene macrosolen* A. Rich.	Caryophyllaceae
9	*Cerastium octandrum* A. Rich.	Caryophyllaceae
10	*Sagina abyssinica* A. Rich.	Caryophyllaceae
11	*Sagina afroalpina* Hedb.	Caryophyllaceae

12	*Anthriscus sylvestris* (L.) Hoffm.	Apiaceae
13	*Agrocharis melanatha* Hochst.	Apiaceae
14	*Apium graveolens* L.	Apiaceae
15	*Helichrysum formosissimum* (Sch.-Bip.) A. Rich.	Asteraceae
16	*Helichrysum splendidum* (Thunb.) Less.	Asteraceae
17	*Helichrysum citrispinum* Del.	Asteraceae
18	*Helichrysum gofense* Cuf.	Asteraceae
19	*Helichrysum nudiflora* (L.) Less.	Asteraceae
20	*Anthemis tigreensis* A. Rich.	Asteraceae
21	*Cotula cryptocephala* Sch. Bip. ex A. Rich.	Asteraceae
22	*Carddus nyassanus* (Engl.) Fries	Asteraceae
23	*Carddus chamaecephalus* (Vatke) Oliv. And Hiern.	Asteraceae
24	*Haplocarpha rueppellii* (Sch. Bip.) Beauv.	Asteraceae
25	*Senecio ochrocarpus* Oliv. and Hiern.	Asteraceae

26	*Senecio farinaceus* Sch.Bip.	Asteraceae
27	*Senecio myriocephalus* Sch. Bip.	Asteraceae
28	*Senecio schultzii* Hochst. ex A. Rich.	Asteraceae
29	*Senecio nanus* Sch. Bip.	Asteraceae
30	*Cineraria deltoidea* Sond.	Asteraceae
31	*Crepis carbonaria* Sch. Bip.	Asteraceae
32	*Arabis alpina* L.	Apiaceae
33	*Arabis thaliana* L.	Apiaceae
34	*Cardamine obliqua* A. Rich.	Apiaceae
35	*Cardamine hirusta* L.	Apiaceae
36	*Trifolium acaule* Steud. ex A. Rich.	Fabaceae
37	*Swertia crassiuscula* Gilg.	Gentianaceae
38	*Swertia kilimandscharica* Engl.	Gentianaceae
39	*Bartsia decurva* Benth.	Scrophulariaceae
40	*Mentha aquatica* L.	Lamiaceae
41	*Salvia nilotica* Juss. ex Jaqq.	Lamiaceae
42	*Satureja pseudosimensis* Brenan	Lamiaceae
43	*Poa leptoclada* Hochst. ex A. Rich.	Poaceae
44	*Bromus leptoclados* Nees	Poaceae

45	*Festuca abyssinica* Hochst. ex A. Rich.	Poaceae
46	*Aira caryophyllea* L.	Poaceae
47	*Poa annua* L.	Poaceae
48	*Carex erythrorrhiza* Bock.	Cyperaceae
49	*Luzula abyssinica* Parl.	Juncaceae
50	*Agrostis viridis* Gouan	Poaceae
51	*Deschampsia flexuosa* (L.) Trin.	Poaceae
52	*Romulea fischeri* Pax	Iridaceae
53	*Cynoglossum amplifolium* Hochst.	Boraginaceae
54	*Cynoglossum coeruleum* Steud. ex DC.	Boraginaceae
55	*Celsia scrophulariaefolia* Hochst. ex A.Rich.	Scrophulariaceae
56	*Alchemilla abyssinica* Fresen.	Rosaceae
57	*Alchemilla microbetula* T. C. E. Fr.	Rosaceae
58	*Galium hochestetteri* Pic. Serm.	Rubiaceae
59	*Rumex nepalensis* Spreng.	Polygonaceae
60	*Conyza variegata* Sch. Bip.	Asteraceae
61	*Drymaria cordata* (L.) Willd.	Caryophyllaceae

62	*Echinops giganteus* A. Rich.	Asteraceae
63	*Carex monostachya* A. Rich.	Cyperaceae
64	*Agrostis quinqueseta* (Hochst. Steud.) Hochst.	Poaceae

Declaration

I, the undersigned, declare that this thesis is my own work and all sources of materials used for this thesis have been duly acknowledged.

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