ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

EFFECTS OF ENVIRONMENTAL FACTORS ON DISTRIBUTION OF VEGETATION ON THE EASTERN SLOPES OF SOUTH WELO HIGHLANDS

By:-MENGISTU GONSAMO
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by

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Abstract

The vegetation of the eastern parts of South Welo was studied in three sites at altitudes of 1,200m-1,500m, 1,700m-2,200m and 2,400m-2,800m using stratified random sampling. From each zone, 18 stands (quadrats) with 20 m x 20 m were selected randomly and totally 54 sample stands were analyzed in which 144 species of plants were recorded and later identified in the National Herbarium (Science Faculty). For each stand, composite soil samples were taken from depths of 0-25cm and analyzed for pH, conductivity, texture, organic carbon, total nitrogen, and available phosphorus. Exchangeable cations (Ca, Mg, K, Na) were analyzed for 5 samples from each zone. Measurement of altitude, slope and soil colour were taken in the field from each stand.

The classification of the 54 stands was conducted by cluster analysis using the computer package SYNTAX. The resemblance index employed was similarity ratio. To analyze species diversity, Shannon-Wiever diversity index was employed. Using this technique, three major clusters (plant communities): Juniperus-Erica type (cluster A), Euclea schimperi type (cluster B), Acacia asak type (cluster C) in descending altitudinal order and nine subclusters designated as a, b, c, d, e, f, g, h and i were identified (where a and b are in cluster A; c, d and e in cluster B and f,g,h and i in cluster C). To compare different clusters and subclusters mean values and one-way ANOVA, followed by Duncan's/Neuman-Keuls multiple comparisons were computed.

The results of the multiple comparison show that the highest number of significant contrasts among the three major clusters were observed from variations in altitudes and related moisture change. Moreover, the three major clusters significantly vary in their texture, organic carbon, and organic matter. There is no significant variation in environmental factors between pair of the subclusters within each zone. The analysis of species diversity show that with decreasing altitude, the richness of vegetation in species composition also decrease.

1. INTRODUCTION

1.1. Statement of the Problem

The diverse topography and climate has endowed Ethiopia with various types of vegetation ranging from desert to afroalpine plant communities (Huffnagel, 1961: 78; Mesfin, 1987: 64; Tewolde Berhan, 1990: 207). Utilization and conservation of the available natural resources in the different vegetation types demand detailed studies of the nature and spatial variation of the different vegetation groups, the factors influencing these variations and, the assessment of human impact on the vegetation, (Mesfin, 1987). Unfortunately, information on vegetation and environment such as spatial distribution of species and ecological processes are inadequate (lacking) in Ethiopia (Friis, 1992: 16; EFAP, 1993: 72). The lack of information on the complex ecological relationships that exist between the plant communities and the physical environment together with the lack of protection and unplanned clearing and exploitation of vegetation have resulted in accelerated rate of soil erosion and land degradation in the northern Ethiopian highlands (Mesfin, 1987: 66). As a result of this unwise exploitation, the northern highlands of Ethiopia which were originally covered with forests and woodlands consisting of Juniperus procera, Olea europaea subsp cuspidata Acacia abyssinica A. pilispina, A. negri, etc. have now been rendered bare Remnant stands of these forests are currently found only on inaccessible mountainous escarpments (Tewolde Berhan, 1990: 210; Mesfin, 1987: 64).

In southern Welo the vegetation has been little studied (Mesfin Tadesse, 1990). However, the available meagre studies and field observations showed that the remnant pockets of natural vegetation are not only restricted to very steep slopes but are also severely threatened because of the encroachment from the local people (SIDA/Welo mission, 1987: 2; Mesfin , 1990: Introduction section; MOA/LUPRD/FAO, 1985:17). According to Mesfin (1990: 4) about 50% of the existing natural vegetation in southern Welo is made up of scattered trees and shrubs of which 30 % is dense bushland. The areas under natural forest accounts for less than 3% of the total vegetation cover. Significant, forest cover is found only in two sites, Mekonnen Lemlem and Anabe areas. According to Mesfin (1990), the plantation of trees and shrubs has not yet significantly contributed to the vegetation cover of the landscape in Southern Welo. Among other things, this devegetation has exposed the soils to severe sheet and gully erosion. As a result, over 50% of the total area of the region has soil depths of less than 10 cm and this is even unsuitable for afforestation (Hurni, 1990: 54).

Thus, detailed studies on the nature, spatial distribution and current status of these vegetation are urgently needed before the forest cover is completely exhausted. The current study is therefore, expected to contribute to the existing knowledge by describing the vegetation types and their current status at micro-environmental level at different altitudinal zones and providing baseline data for environmental planners and decision makers in the study area as well as other areas with similar environment.

1.2. Objectives of the study

The general objective of this study was to identify and classify the vegetation in Southern Welo and relate distribution and occurrence of vegetation with different environmental factors in the study area. Thus, this study had the following specific objectives:

- to identify and the study vegetation types and their pattern of distribution in the study area ;
- to find out the relationships between vegetation and environmental factors at different zones;
- to assess some of the current human impact on the vegetation at different altitudes;
- to give some recommendation on the possibilities for conservation of the vegetation resources.

The following basic research questions were drawn from the above objectives to guide the investigation :

What type of vegetation are there along the escarpment? What ecological relationships exist between vegetation and other environmental factors such as soil, altitude, slope, etc. in the study area? To what extent is the disturbance of vegetation in the study area relate to human activity?

1.3. Physical Background of the Study Area

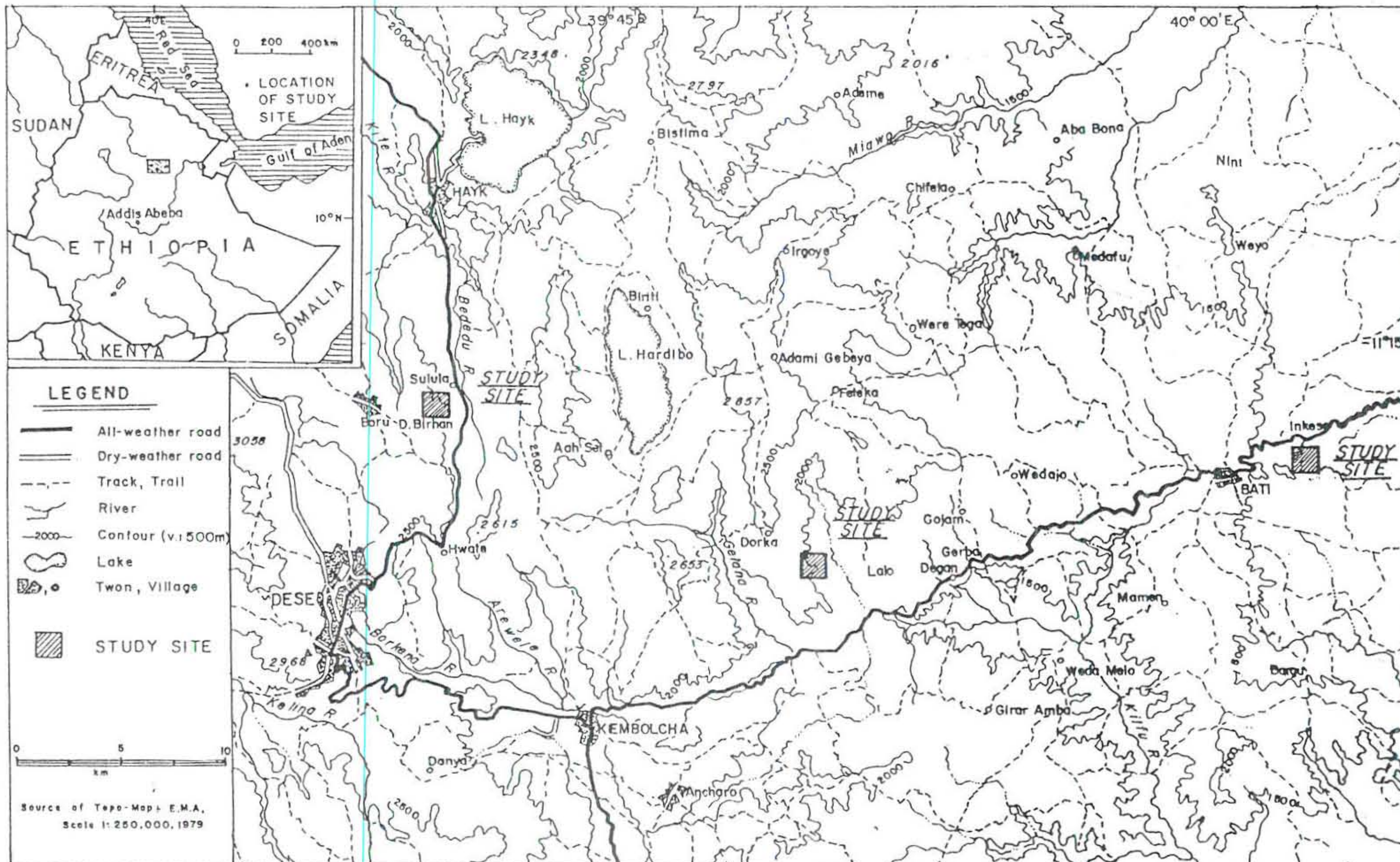
1.3.1. Location, Topography and Geology

The study area is located in Welo along the Eastern escarpment of the northwestern highlands (south Welo) approximately between 39°38' - 40°02'E longitudes and 11°13'N - 11°14'N latitudes (see Figure 1). Topographically, the study area is very rugged comprising flat to undulating plains, mountains, numerous gullies along the slopes, ridges, etc. The highest peak in the area rises to about 3000m at Tossa. The variation in altitude coupled with the diversity of topography and other environmental factors has resulted in different vegetation types and soil characteristics.

Borkena and Cheleka are the major rivers which drain into Awash river in the rift valley. These rivers are fed by numerous streams and tributaries specially during the rainy seasons. Geologically, the study area as presented by Bille and Haywood (1983: 6) can be divided into two. The first which covers an extensive area is covered by volcanic rocks of Ashangi group belonging to Palaeocene, Oligocene and Miocene periods. This group includes basalt, with the Trap series, Olivine, Tuffs and rare Rhyolites, or Doleric sill and Gabrodiabase intrusive. The second which is covered by the Magdala group of formation (upper Miocene and Pleistocene) includes Rhyolites, Trachytes, Rhyolitic and Trachytic Tuffs, Ignimbrite, Agglomerates and Basalt.

4a

Fig:- I LOCATION OF THE STUDY AREA



1.3.2. Climate

The highlands of Welo are located on the leeward side of the main moisture bearing winds(Summer) and therefore receive less rain than the western side of the highlands at the same altitude (SIDA/Welo mission, 1987: 2). Because of the lack of long-term and complete climatological records for Welo, it is difficult to precisely establish the pattern of the climatic condition in the study area. However, on the basis of the available information, the rainfall regime in Welo is found to be bimodal with two distinct rainy seasons_ the short rain (the Belg) and the main summer rain (Kremt) seasons (Table 1 and Fig.2) (Bille and haywood,1983; SIDA/Welo mission, 1986,Belay,1998).

The rainfall data of the three stations recorded at altitudes of 2,460$_m$ (Dessie), 1,903$_m$ (Kombolcha) and 1,660$_m$ (Bati) (see table 1), confirm the bimodality of the rainfall in the area (see also Fig.2). As the table shows, throughout the escarpment (starting from Bati to Dessie), the seasonal pattern of rainfall distribution is almost similar. Accordingly, there are two distinct periods of rainfall,that extend from March to May (short rain) and from July to September (long rains)(Fig.2). However, the total amount of annual rainfall shows variation among the three stations. The result indicates that the total amount of annual rainfall increases from Bati to Dessie following the altitudinal gradient. For example, the total amount of annual rainfall was 939 mm in Bati; 1017 mm in Kombolcha and 1188 mm in Dessie(Table 1).

Table 1. Rainfall and Temperature Data for Three Stations (Dessie, Kombolcha, and Bati)

Station	Altitide		Jan	Feb	Mar	Apr	Ma	Ju	Jl	Au	Sp	Oc	No	De	Ann.
Dessie	2460m	Rain f.	24	40	79	101	77	60	273	283	157	48	23	23	1188
		Temp*	14	15	14	16	16	17	17	16	15	14	13	13	15
Kombolcha	1900m	Rain f.	24	39	77	99	67	31	243	244	120	35	19	19	1017
		Temp	14	16	17	18	18	20	19	18	17	15	14	14	17
Bati	1660m	Rain f.	39	97	70	95	47	11	193	202	96	29	6	54	939
		Temp	17	17	18	19	20	22	22	20	20	17	15	15	19

Source: Row Data from National Meteorological Agency *MOA/LUPRD/FAO, 1985: 11

Note: a) Rainfall Data for Dessie are averages of 35 years (1962_1996)

b) Temperature Data for Dessie are averages of 18 years (1962_1980)

c) For Kombolcha Station both rainfall and temperature data are averages of 34 years (1962_1995)

d) Rainfall and temperature data for Bati are averages of 7 years (1989_1995).

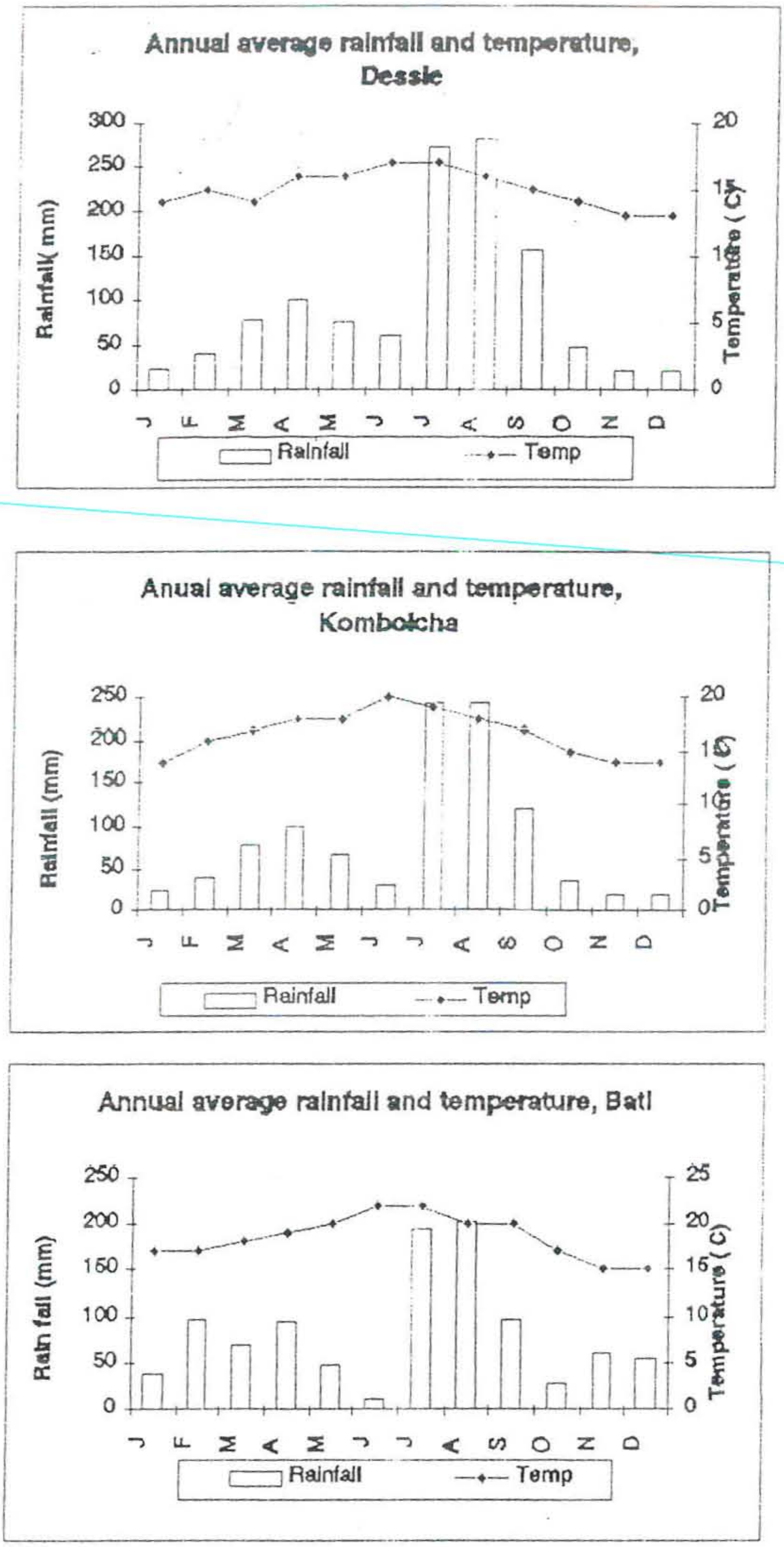


Fig 2 Pattern of Rainfall and temperature in the Study area

Temperature, also shows variation with altitude . As the temperature records from three stations cited above (table 1) show the distribution of temperature is inversely related to altitudinal gradient,that is, it increases towards the lower altitudes. It increases from Dessie towards Bati and down to the Afar plain. The average annual temperature increases from 15°C at Dessie to 17°C at Kombolcha and rises to 19°C at Bati area. In the study area on altitudes above 2,500m frost is frequent in the dry reasons (SIDA/Welo Mission, 1987: 2).

1.3.3. Soils and vegetation

The soils of the study area have been studied by several researchers/organizations (Belay Tegene,1998; MOA/LUPRD/FAO, 1985; Bille and Haywood, 1983, etc). These studies show that the major types of soils in the study area are Vertisols, Cambisols, Leptosols, Regosols, Fluvisols, etc.The spatial pattern of these soils vary according to variation in landform units. The Leptosols, which are common in the study area are, shallow soils mainly found on the ridge crests, backslopes and upper footslopes(Belay,1998).

Most of the original vegetation in Welo has been removed. From the remaining scattered patches on some mountain/hillside slopes, the original vegetation of southern and central Welo is characterized to have been a dry evergreen fores composed of:Podocarpus gracilior , Juniperus procera , Ficus sp., Olea eurpaea subsp. cuspidata, Croton macrostachys , Myrsine salicifolia, Ekebergia rueppelliana, Maesa laceolata, Acacia abyssinica, A. albida, Pittosporum viridiflorum, etc (Mesfin,et.al,1987;Mesfin,1990). These original vegetation are restricted to isolated slopes particularly on Yegof, Anabe, Tossa, Gerado, etc.slopes.

With regard to land use, most of the land at higher altitudes of the study area is mainly cultivated. But most of the land in the lower Bati area is covered with scattered shrubs. The study of MOA/LUPRD/FAO, 1985 shows that in the study area, most of the land which is suitable or marginally suitable for cropping is cultivated and the vegetation, although generally degraded, is confined to periodically flooded areas and in steep slopes. In some cases, land upto 70% slope gradient is cultivated. With regard to the distribution of major crops in the area, in the upper(Dega)area, Barley, Wheat, Teff, Oats, Chick Peas, Horse Beans, Peas, Maize (small) Beans, etc. are the most important crops. Of these Teff, Wheat and Barley are cultivated twice a year (personal communication with local people). In the middle (Woina Dega) altitudinal zone, the dominant crops are: Teff, Maize, Sorghum and Wheat. In this zone, Pulses are considered as secondary crops. In the lower(Kolla) area, Sorghum, Teff and Maize are the important crops; Chick Pea being a secondary crop (see also Dessalegn, 1991: 47). In addition, in the lower Bati zone the main occupation of the people is pastoralis,that is, rearing domestic animals such as cattle, goats and camels.

2. Literature Review

2.1. Considerations in Vegetation Survey

2.1.1. Vegetation Sampling

The constraints of time, labour and money to study all of the vegetation groups in a given area necessitate the use of samples (Daubenmire, 1968:80; Kellman, 1980:124). The most important elements which the vegetation samples should include according to Whittaker (1973: 9) are:

1. a list of plant species present in a given study area, the plot or quadrat;
2. some indications of relative importance of these species (and usually of their growth, heights, and stratal relationships,) and
3. relevant information on environment, soil, community structure and evidence of disturbance and community change.

The samples to be representative of the whole community, should also embrace a minimum variation in topography (Daubenmire, 1968: 80).

In vegetation sampling the widely used procedures are: random, systematic or the combination of the two methods (Greig-Smith, 1964: 24). The advantages and disadvantages of these methods were discussed by many researchers such as ; Greig-Smith (1964) ; Tewolde Berhan (1969) ; Chair et.al.(1983) ; Ferede (1984) ; Kebrom (1984). Accordingly, if samples are taken at random, the estimate of mean value, as well as the estimate of the precision of that mean can be available which the systematic sample lacks

(Greig-Smith, 1964: 21). However, if the distribution of vegetation is not random, the representation is highly likely to be biased (Mueller-Dombois and Ellenberg, 1974: 38). If vegetation shows some regular pattern, systematic sampling is preferable. However, the latter is also prone to subjectivity, as the standard error and the test of significance cannot validly be evaluated from the data. It may also highly exaggerate the error if used in areas of periodic type of variation or if the interval between the successive units in the sample happens to coincide with wave length or a multiple of it (Snedecore, 1967). The method which combines advantages of both random and systematic samples is stratified random sampling. In this method, vegetation segment is subdivided into several more or less even sized subsegments. From these subsegments samples are laid out at random. Here sampling in each subdivision ensures coverage across the whole vegetation segment, while the random location of sampling sites within the subdivisions allows for the establishment of statistical error terms (Mueller - Dombois and Ellenberg, 1974:39).

This stratified random sampling technique was used by MOA/LUPRD/UNDP (1985) in the survey of vegetation and landuse of Borkena area (Welo). They asserted that they did not use systematic sampling because it takes much time to cover the main variation. This technique also helped them to map all units of vegetation and land use equally and reliably in reasonably short time, and that no specific land use or vegetation type was over_ looked. Therefore, since the current study area is not uniform topographically and its area is vast, this technique of sampling was chosen.

Besides the sampling procedures one should also consider the shape and size of the sample plots at the out set of the research work (Mueller-Dombois and Ellenberg, 1974: 31, Greig-Smith, 1964: 26). The shape of quadrat has been almost traditionally a square (Kershaw, 1973: 32). The problem resulting from the use of square, however, is the edge effects, whether the species at the edge is 'in' or 'out' of a quadrat. This can be slightly reduced if the perimeter is reduced relative to the area and this can be achieved by using round quadrat (Gold-Smith and Harrison, 1976). In addition to the shape, the size of the plot can also influence the collected data. If the plot is too small, infrequent species will be under-represented; where as if the plot is too large, a greater number of species, which really do not correlate with the group will be added and also needs more time to make observation (Chair et.al. 1983: 361; Kershaw, 1964 in Mueller-Dombois and Ellenberg, 1974: 361). Therefore, the correct size of the plot depends on the size of plants to be studied (see Daubenmire, 1968: 83; Kershaw, 1973: 31). Many Workers therefore, suggest the use of sub plot method. In this method, one can start with small plot to record smaller plants and increase the size of the plot as the size of the plants increase. For example, the size of the quadrat ranges from 20cm x 50cm for meadows, pastures, etc. to 1mx1m for herbaceous vegetation and 10m x 10m or more for trees, (Fueller and conard, 1965: 27; Daubenmire, 1968: 88; Kellman, 1980: 124; Chair et.al 1983: 368-9). Though different quadrat sizes are suggested by different authors to study vegetation, many researchers in Ethiopia and elsewhere use the quadrat size of 20m x 20m to sample forest or woodland vegetation (see Lawton, 1978; Sebsebe, 1980; Hailu, 1982; Tewolde Berhan, 1974 in Sahle, 1984; Ferede, 1984; Kebrom, 1984; Sahle, 1984; MOA/LUPRD/UNDP, 1985; Lisane work, 1987). For this reason,the plot size of 20m x 20m was employed in this study.

3.1.2. Approaches in Vegetation Analysis

Currently, there are a wide variety of multivariate techniques to summarize the complex data of plant communities. These are primarily based on two popular approaches (theories): classification and ordination, (Greig-Smith, et.al, 1967: 483; Anderson, 1965: 521). These two approaches are based on two differing concepts regarding the nature of vegetation. Classification is based on the hypothesis that the distribution of vegetation is discontinuous (discrete-community concept); where as the supporters of ordination technique emphasize the continuity of vegetation (continuum concept), (Greig-Smith, 1964: 158; Anderson, 1965: 521). These two theories largely originated from the ecologists living in different environmental (topographical) conditions. The supporters of the discrete community concept were largely from mountainous areas and those who propose the continuum concept were from the areas of gentle topography (Beals, 1969: 981).

Classification involves arranging the stands into classes, the members of each of which have common attributes setting them apart from the members of other classes. Whereas in ordination technique stands are placed in relation to one or more axes in such a way that a statement of its position relative to the axes conveys information about its composition (Greg-Smith, 1964: 168; Kershaw, 1968: 467; Anderson, 1965: 522). Each of this techniques has advantages and disadvantages. Classification simplifies heterogeneous data but its problem is that it may result in an over-emphasis of discontinuities and it is more qualitative, where as ordination technique is not satisfactory if applied to heterogeneous data (Greig-Smith, 1964: 161).

Inspite of their differences, both methods are complementary in the thorough description of a restricted vegetation region or widely distributed vegetation. Both methods also compete in the treatment of sample data. If sample stands are floristically complete, the data collected for one method can be used for the other as well. The choice of any one of these methods is a matter of taste, and should be guided by the intended use of the results (Mueller-Dombois and Ellenberg, 1974: 41; Whittaker, 1973: 604; Tewolde Berhan, 1969: 58). Many researchers emphasize that for vegetation mapping or landscape inventory, classification is greatly to be preferred and more informative; whereas for understanding the sociology of plants or vegetational characteristics of the site ordination technique is more efficient (Beals, 1969: 985; Whittaker, 1973: 604).

In the present study, only classificatory techniques are employed. Different types of classificatory techniques, their advantages and disadvantages were reviewed and discussed by different researchers(see for example, Tewolde Berhan, 1969; Pielou, 1969; Everitt, 1980; Mueller-Dombois and Ellenberg, 1974; Digby and Kempton, 1987; Zerihun, 1985, Tamrat, 1993). Gauch (1982) groups these classification techniques into three : table arrangement, non-hierarchical classification and hierarchical classification, (see Lisane work, 1987: 25 and Sahle, 1984: 25). Table arrangement is the earliest classification technique in community ecology. The table work of Braun-Blanquet starts by ordering the rows and columns of the species-by- sites matrix to bring together sample sites with a similar species composition, and species with a similar distribution over sites (Digby and Kempton, 1987). For the detailed analysis of tabular arrangement see Mueller-Dombois and Ellenberg (1974: 177).

Non-hierarchical classification merely assigns each item to a group and in many of these methods there are computational difficulties. Moreover, the clusters in these methods are defined separately and the links between them have the form of a net- work rather than a dendrogram (Pielou 1969); the detailed analysis was given by Digby and Kempton (1987). The hierarchical method of classification arranges the group into a hierarchy and the classes at any level are the subclasses of classes at a higher level, (Digby and Kempton, 1987: 124; Pielou, 1969: 238). This technique is further subdivided into agglomerative and divisive methods. The agglomerative method initially considers each unit as being a separate group and begins with the computation of a similarity or distance matrix between the entities, and proceed by repeatedly combining the two closest groups until only a single group remains. It ends with a dendrogram showing the successive fusions of individuals (see Everitt, 1980: 25; Digby and Kempton, 1987: 124). There are different techniques to arrive at the similarity levels such as single linkage, complete linkage, average linkage, centroid methods, etc. However, the basic procedures in all the methods are the same (the detailed analysis of the methods is given in Everitt, 1980; Digby and Kempton, 1987; Pielou, 1969).

The divisive classification results in separate units by repeatedly dividing and redividing the whole quadrate collections (Pielou, 1969:238; Everitt, 1980:24; Digby and Kempton, 1987:124). As discussed in Pielou (1969); Digby Kempton (1987) Kellman (1980); Everitt (1980) , the hierarchical classification may take: monothetic divisive, polythetic divisive, and polythetic agglomerative forms. Monothetic divisive technique operates only on binary data and each group division is based on the state of a single species. In this method, two sister groups are distinguished by the fact that one has and the other lacks a single attribute. The polythetic divisive technique uses all species in classifying samples to smaller hierarchy through successive redivisions. Whereas the polythetic agglomerative classification takes information on all attributes and form single group through successive fusions, (the details of these different methods are discussed in Everitt, 1980; Digby and Kempton, 1987; Lisane work, 1987; Pielou, 1969; Sahle, 1984. For the analysis of data in the present study, hierarchical, polythetic and agglomerative technique was employed.

2.2. Vegetation and Environment of Ethiopia

2.2.1. General Survey

Until recently, description or surveys of Ethiopian vegetation were mostly done by foreign travellers who came with missions other than floristic surveys (Tamrat, 1993: 11; Mesfin, 1987: 66; Friis 1992: 12). Of those travellers who initiated plant collection in this country, James Bruce (1730-1794), E.S. Rueppel (1832-1833), W.G. Schimper (1837), R. Quartin-

Dillon (1835-1840), E. Ruspoli and D. Riva ((1840-1894), O. Neuman (1902-1903), etc. can be cited (Friis, 1992: 12; Mesfin, 1987: 66). Most of these surveys were botanical explorations and on the basis of these reports and later on accounts, the basis for the understanding of the country's vegetation and its classification was laid (Friis, 1992: 12; Tamrat, 1993: 11; Mesfin, 1987b: 66).

As indicated by Lisane Work (1987), Tewolde Berhan, (1990), Friis, (1992), Tamrat, (1993) and Sebsebe, (in press) the earliest and more elaborate description and classification of the country's vegetation was contributed by Pichi-Sermolli, (1957) and Breitenbach (1961, 1963). In order to establish a geobotanical map of Ethiopia and Somalia, Pichi-Sermolli, (1957) considered 24 vegetation units, (EMA, 1981; Tamrat 1993; Lisane Work, 1987). On the basis of altitude or temperature, Breitenbach, (1963: 13) recognized seven vegetation zones in Ethiopia. Accordingly the lowlands are characterized by steppes, savannas and woodlands, while the highlands are occupied by forests which change in the higher mountains again to woodlands, savannas and steppes. On the basis of the classification of these authors, different people have been classifying the country's vegetation into several units taking different factors into account. For example, based on the classification of Pichi-Sermolli (1957), Huffnagel, (1961) divided Ethiopian vegetation into 10 types; EMA (1981) into 12 types and Westphal (1975) into 16 units. UNDP/FAO (1984) categorized the Ethiopian vegetation into 8 types and based on the Breitenbach's classification; Daniel, (1977) classified Ethiopian vegetation into 10 categories. More recently, EFAP (1994) identified four main phytogeographical areas and nine distinct major vegetation zones with in these four areas.

In a similar manner, different descriptive and classificatory studies were conducted at a local level, by relating vegetation and the environment (Sebsebe, 1980; Zerihun, 1980; Hailu, 1982; Zerihun, 1985; Isaac, 1984; Tewolde, 1990: Tamrat, 1993; Lisane Work, 1987; Kebrom, 1984; Ferede,1984). These studies were thoroughly reviewed by Tamrat, (1993) and Lisane Work (1987).

These studies argue that the spatial distribution of vegetation varies on the basis of the variation in altitude, temperature, moisture, etc. (Friis, 1992; Tewolde Berhan, 1990: Tamrat, 1994; Sebsebe, in press; Lisane Work, 1987; and Beals, 1968). Even the same type of vegetation would have different altitudinal limits at different locations because of the various environmental variables. This was observed by Tewolde Berhan's study on Ethiopian highlands particularly in the Afroalpine and Afromontane belts(Tewolde Berhan, 1990). This study shows that in northern Ethiopia,the lower altitudinal limits for the Juniperus procera forests is 2,200 m and it is 1,500 m in southern Ethiopia. The broad-leaved deciduous forests are found upto the altitudes of 1,700 m in northern Ethiopia, which is about 900 m in southwest Ethiopia. Similarly, the Acacia woodlands and sclerophyllous evergreen scrub are found upto the altitudes of 1,900 m in northern Ethiopia, which are restricted to altitudes below 1,500 m in south. These variations in altitudinal limits is according to Tewolde Berhan is primarily due to decrease in moisture in northern Ethiopia.

2.2.2. Vegetation of Southern Welo

Welo is one of the regions in Ethiopia where little botanical exploration has been made(Mesfin, 1990; Sebsebe, in press).

The previous local studies undertaken in the area saw vegetation in relation to some environmental factors. Some have discussed vegetation in relation to altitudinal gradients, others in relation to land use and still others saw in relation to soils. Beals' (1969) study entitled "Vegetational change along altitudinal gradients," mainly investigates to the zonation of plants, that is, whether the distribution of vegetation is discrete or continuous. To this end, he took two characteristic areas; one from the rift valley with the altitudes of 1,000 to 1,900m and the other from the rift escarpment (steep gradient) with altitudinal range of 800 to 2050m. His major finding was that on gentle gradient (rift valley), the change of vegetation is gradual (continuous) where as in the case of steep gradient (rift escarpment), the change of vegetation is sudden (discontinuous) though this is some times disturbed by other environmental factors.

Another important study in the area is that of Bille and Haywood (1983). The major emphasis of their study was to relate vegetation to landuse and ecology. They surveyed the vegetation of the whole north-central highlands of Ethiopia using the systematic field observation methodology. Using this method, they classified the vegetation of their study area into seven general vegetation zones and nine detailed plant associations with special reference to Ambassel wereda and its immediate surroundings.

A study of MOA/LUPRD/UNDP, (1985) had also the objective of relating vegetation and land use in the Borkena catchment. They classified the vegetation of this catchment into five groups (forest, woodland, bushland, shrubland and grassland).

According to Sebsebe(in press), the vegetation of central and southern Welo is represented by dry evergreen forest and grassland, the evergreen scrub, the Acacia (_Commiphora) woodland and the marshy vegetation types. Most of this original vegetation has been removed and from the remaining patches on isolated slopes by ERCS (1986), Mesfin, et.al,(1987), Mesfin (1990) and Sebsebe (in press), the floristic composition and distribution of vegetation is summarized as follows:

According to these authors, the vegetation in the area is grouped into (indigenous and newly planted categories of trees and these different types, here occupy different altitudinal zones. The vegetation types between Boru Meda and Boru Debre Birhan Sillasie (2660m) is considered as evergreen afromontane forest and grassland. The flosistic composition of this vegetation group includes: native tree species mainly consisting of: Ekebergia capensis, Erythrina brucei, Juniperus procera, Olea europaea subsp. cuspidata and Maytenus obscura; shrubby species, such as Berberis holstii, Calpurnia aurea, Discopodium penninervium, Dovyalis abyssinca, and Maytenus arbutifolia; succulents include: Aloe debrana, Plectranthus assurgens, and herbs such as Anthospermum herbaceum, Alchemilla sp., Campanula edulis, Cynoglosum coeruleum, Eulophia streptopetala, Kniphofia foliosa, and Nepeta azurea. The genera Cynodon and Hyparrhenia include the main grass components. Introduced tree species in the area include Eucalyptus camaldulensis and E. globulus.

In the area lying between lakes Hayk and Ardibo at altitudes of 2000 to 2400m, most of the land is cultivated and from the remaining large trees on hill tops and in inaccessible parts of gullies, the natural vegetation includes, tree species such as Acacia abyssinica, A. lahai, Bersama abysinica, Celtis africana, Cordia africana, Croton macrostachys, Ehretia cymosa, Teclea simplicifolia; shrubby species include Carisa edulis, Dodonaea angustifolia, Lantana trifolia, Sesbania sesban, solanum incanum, Vernonia amygdalina; succulent species such as Euphorbia candellabrum, and Aloe camperi and herbs such as Coronopus didymus, Datura stramonium, Echinops pappi, Nicandra physaloides, Rumex nepalensis, Rumex nervosus and Tribulus terrestris. Hyparrhenia and Pennisetum include the dominant grass species. At higher altitudes (2,400mto 2,700m) of these areas, Podocarpus falcatus, Olea eurpaea subsp. cuspidata, Ekebergia capensis, Acacia abyssinica, Erythrina brucei, Maesa lanceolata Juniperus procera and Rhamnus prinoides are the major tree species. The vegetation around the two lakes consist of marshy species. The currently planted species of trees in the area are Acacia and Eucalyptus.

Most of the hill and mountain slopes between Dessie and Kombolcha are sparsely covered with trees and shrubs of Juniperus procera, (above 2000 m), Acacia abyssinica, Acacia lahai, Cordia africana, Euclea schimperi, Dodonaea angustifolia, Calpurnia aurea, Croton macrostachys, Pterolobium stellatum, Rhus vulgaris, Rumex nervosus, Dovyalis abyssinica, and Lippia adoensis.

The major vegetation type on the slopes between Kombolcha and in the vicinity of Bati at altitudes between 1,900-1,150m, is a dry Acacia-Euphorbia - Dicrostachys deciduous woodland with the major shrubby species such as Euclea schimperi, Dodonaea angustifolia, Acacia lahai, Diospyros abyssinica, and Calpurnia aurea growing at higher altitudes and Acacia asak, Acacia oerfota, Acacia senegal, Dobera glabra, Acacia tortilis, Balanites aegyptiaca, Delonix elata and Berchemia discolor are restricted to altitudes below 1,500 m. The main grass species in these areas are Enteropogon macrostachys and Pennisetum setaceum.

The current study, though, its areal coverage is small, relates vegetation with soil and other environmental factors taking spatial pattern into account. It investigates in detail the type of vegetation and its pattern of distribution along the escarpment so that the factors responsible for this pattern are identified and explained.

3.Materials and Methods

3.1. Vegetatin Data Collection and Analysis

3.1.1. Vegetation Data

In order to identify and classify the vegetation types in relation to environmental factors in South Welo highlands, stratified random sampling technique was employed. This sampling procedure was adopted because the area surveyed was very large, rugged and the existing vegetation occur in isolated patches on slopes. Accordingly, the whole area was divided into three zones following traditional altitudinal classification of Ethiopia: Kola, Woina Dega and Dega with respective altitudes ranging between 500-1,500m; 1,500-2,300m; and 2,300-3,200m. In the zones three areas were identified from the Map with the scale of 1: 50,000. From each site, an area of about 1Km^2 was selected between altitudes of 1,200-1,500 m; 1,700-2,200m and 2,400-2,800 m. From each sample site, 18 quadrates (stands) with the size of 20 m x 20 m were randomly selected by first drawing a grid over the base map and numbering the grid lines. Within each quadrat of 20 m x 20 m species of trees, shrubs and herbs were collected, recorded and identified. With in the sample plots, the trees and shrubs were counted and herbs were estimated using the 1-9 modified Braun-Blanquet scale (Westhoff and van der Maarel, 1978, van der Maarel, 1979, cited in Tamrat, 1993). These are:

1. (rare)
2. (occassional)
3. (abundant)
4. (very abundant)
5. (cover 5-12.5%)
6. (cover 12.5_25 %)
7. (cover 25_50 %)
8. (cover 50_75 %)
9. (cover >75 %)

3.1.2 Vegetation Data Analysis

All in all a total of 54 quadrates were sampled from the study area in which one hundred forty four plant species were collected. These were pressed, dried and identified. The specimens were deposited at the National Herbarium (ETH), Science Faculty (see Appendix 1 for species list). To obtain a clearer picture of the vegetation and associated environmental factors in the study area, the species identified should be summarized and classified. In order to analyze and summarize the complex vegetation data, multivariate techniques such as classification and ordination are generally used (detailed analysis of each of these methods is given in section 2). However, in the present study, the objective was to classify the vegetation of the study area and therefore, only a classificatory technique was employed.

To classify vegetation, the hierarchical agglomerative classification with similarity ratio as a resemblance index (cluster analysis) was used. The computer package employed for the analysis was SYNTAX:(programme NCLAC_Hierarchical clustering by distance optimization) following Podani, 1988. This method operates on nxp (sample-by-species) matrix of similarities among a set of units. It starts from the whole quadrat collection, and the distance (similarity) between pairs of quadrates was calculated and arranged in a similarity matrix. Then the two quadrates with the highest similarity (the smallest distance) were joined into a single group. Then, the similarity (distance) between this group and the remaining species are calculated. Again, the two closest quadrates (quadrates with highest similarity) will be joined into one group. This process is repeated until all the clusters are merged into one group (see Chatfield and Collins, 1980: 222; Digby and Kempton, 1987: 125, Berry, 1984: 118).

To assess the species richness relative abundance (species diversity) among three major clusters, the Shannon-Weiver diversity index (Shannon, 1949) (the program shannon) was employed using the modification by Zerihun Woldu (1989) ($H= - \sum_{i=1}^{n} pi ln pi$). This index measures the species diversity (species richness and relative abundance).

To see whether there is significant variation among different clusters in environmental variables, the one-way Analysis of Variance (ANOVA) was conducted. This was followed by the analysis of Duncans/Neuman-keuls multiple comparison, to see whether there is significant difference in environmental factors, between pairs of clusters. The environmental factors were also averaged and compared with each other.

3.2. Soil Data Collection and Analysis

3.2.1 Soil Data Collection

Since one of the main objectives of this study was to establish relationships between vegetation and edaphic factors, a composite soil sample was taken from each (20 m x 20 m) sample quadrat established to study the vegetation. Accordingly, four soil samples from the corners and one from the centre of each quadrat were taken from the depths of 0-25 cm using auger.All samples within the quadrat for the depth of 0-25 cm were mixed thoroughly and about a kilogram of soil was taken in plastic bag for laboratory analyses. In addition, at each sample site, the total depths of the soil was measured and the average recorded. Different characteristics of the soil such as structure, texture, drainage, etc. were described at each auger hole site using the standard procedures of FAO/UNESCO (1990). Soil colour was determined in the field at moist state using the Munsell soil colour chart (1994). Altitude and slope were measured by altimeter and abney level respectively. The land use, micro-topography, surface stoniness and the observed signs of human interferences were also noted(see table 2).

3.2.2. Soil Data Analysis

The laboratory analysis of the soil data was done at the National soil laboratory of the Ministry of Agriculture. In the soil laboratory, soil samples collected from each stand were air dried, crushed sieved using a 2 mm sieve, and then, the following properties were determined (Table 2, number 7).

Table 2 **Environmental data generated and methodes employed**

	Data Generated	Instruments/Methods Employed
1	Micro-topography	-field observation
2	Slope	-Clinometer/ abney level
3	Altitude	-altimeter
4	Parent Material and Surface characterstics	-rock outcrop and/or surface stoniness (FAO/UNESCO, 1990)
5.	Human interference	- observation, discussion with farmers
6.	Physical properties of soil	
	a) Soil depth	- Measurement
	b) Soil colour	- Munsell soil colour chart (1994)
	c) Soil texture	- feel method or finger texturing
7	Laboratory Analysis	
	a)Texture	- Hydrometer method following modified Bouyoucos method. Percentage of sand,silt and clay were determined following USDA particle size classification
	b) pH	- 1:2.5 soil-water suspension
	c)organic carbon	- Walkley and Black method
	d) total nitrogen	- Kjeldahal method
	e) available phosphorus	- Olsen method
	f) conductivity	- Beckman Chem Mate conductivity meter
	g) exch. Ca,Mg, K, Na	NH_4OAc method (ammonium acetate)

4. Results and Discussion

4.1 Results

4.1.1 Vegetation Classification

The classification of vegetation was performed by cluster analysis using the computer package SYNTAX (Podani, 1988) . The resemblance index employed was similarity ratio. Using this method, three major clusters designated as A, B, C at a higher level of hierarchy and nine subclusters designated as a, b, c, d, e, f, g, h and i at a lower level of hierarchy were identified (Fig. 3 and Table 3). The Y- axis on the dendrogram represents the distance (dissimilarity level) and on the x-axis various groups of stands are arranged. Each cluster is found to be distinct in the floristic composition of vegetation except some plants which were observed throughout the clusters. The common characteristics of vegetation throughout the study area is that most of the plants are evergreen, but with decreasing altitude, short evergreen shrubs become dominant.

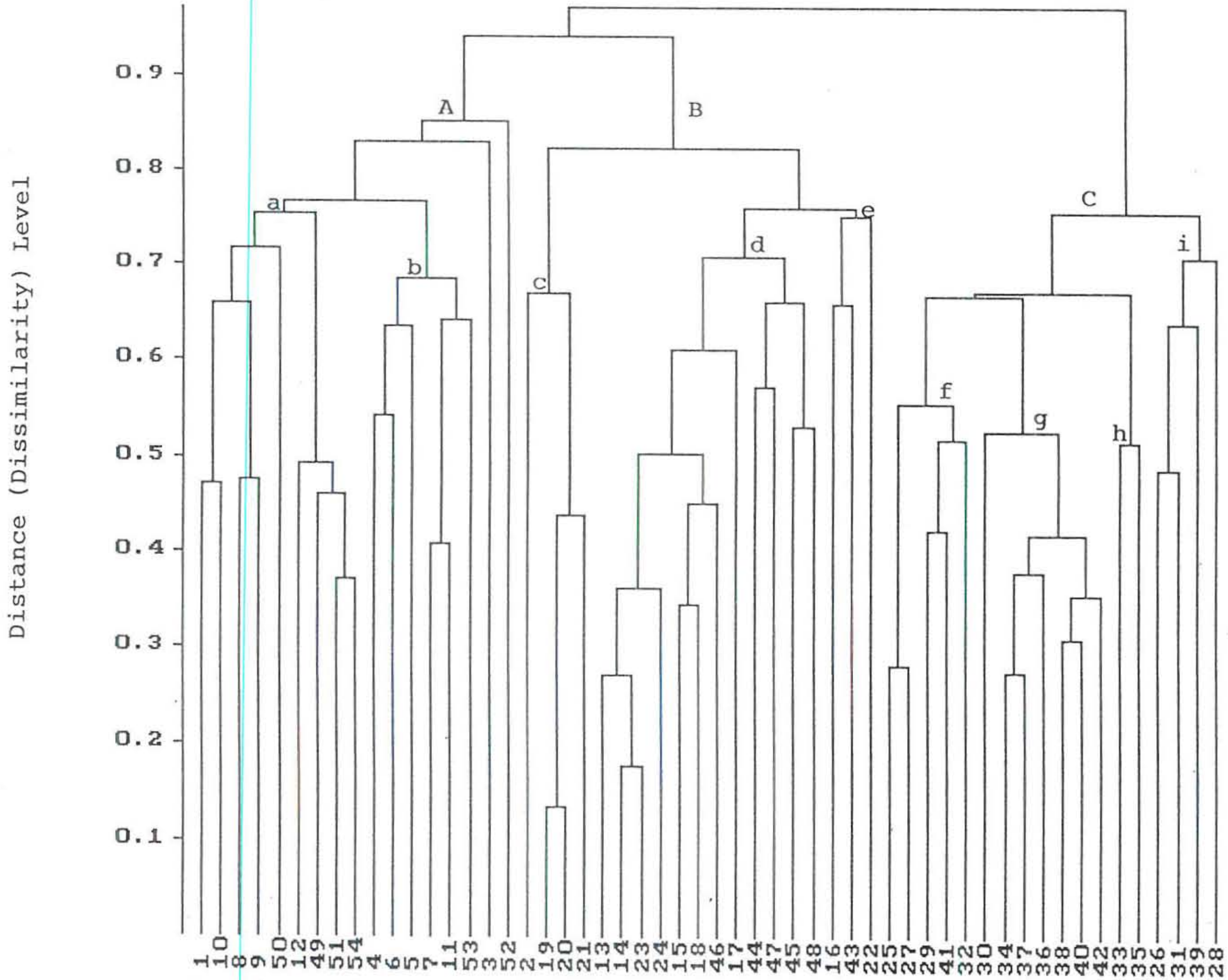


Fig. 2. Dendrogram showing major clusters (capital letters)and subclusters (small letters)

Table 3. Stand (Quadrat) Composition of the clusters

Clusters	Stand (Quadrat) Composition
A (a)	1,10,8,9,50,12,49,51,54 (52 and 3 are outliers)
(b)	4,6,5,7,11,53
B (c)	2,19,20,21
(d)	13,14,23,24,15,18,46,17,44,47,45,48
(e)	16,43,22
C (f)	25,27,29,41,32
(g)	30,34,37,36,38,40,42
(h)	33,35
(i)	26,31,39,28

Note: Letters in the parenthesis show subclusters

4.1.2. Species Composition of Different Clusters

The result of the classification shows three major clusters and nine subclusters. The communities were grouped based on the relative magnitude of mean cover-abundance values of modified Braun-Blanquet scale (see section 3). These communities were named after one or two of the dominant species and they were described as follows:

4.1.2.1. Juniperus- Erica Type (Cluster A)

There are 17 stands (quadrates) in the major cluster A (Table 3 and Figure 3) which are found in Mofa, Bededo farmers association between altitudes of 2,500 to 2,800 m in the vicinity of Mofa Kidane Mihiret church. Some of the species in this community such as Juniperus procera, Olea europaea subsp. cuspidata represent the hard indigenous species which are tolerant to drier conditions (Legesse,1995). These species of plants grow in association with many other plants. This community, which is generally dominated by Juniperus procera,Olea europaea subsp. cuspidata trees and Erica arborea shrubs, is divided into two main subclusters, a and b. Subcluster 'a' mostly consisted of remnant dry evergreen forest vegetation and subcluster b is dominated by the vegetation regenerated after the closure of the area. The dominant plant species in each subcluster were different from one another as will be seen from successive discussions (see the dominant plant species in each subcluster below and full species list is given in Appendix 2). Stands (quadrates) 52 and 3 are outliers, meaning, they do not resemble other groups due to the dominance of different plant species in them. The former is dominated by various herbaceous plants (especially Kalanchoe deficiens) while the latter is mostly covered with Dodonaea angustifolia . Therefore, on the dendrogram both stands show different pattern. The species composition and characterstics of two subclusters (a and b) are as follows:

Subcluster 'a' is found in the immediate vicinity of Mofa Kidane Mihiret church and is relatively well protected from human interference for longer period and therefore, represent the remnant forest vegetation in the area. The dominant species of trees in this subcluster are Juniperus procera , Olea europaea subsp. cuspidata, Nuxia congesta and Rhus vulgaris. This subcluster is also dominated by shrubs like Erica arborea, Berberiis holstii, Myrsine africana and Maytenus senegalensis . Panicum pusillum and Hyparrhenia hirta are the main grass species. The major herbaceous plants in this subcluster consist of Kinphofia foliosa,Polygala rupicola,Phagnalon abyssinica, Pelarogonuim alchemilloides and Hypoestus forskalei. Most of the ground layer and tree trunks in this subcluster are densely covered with mosses. Moreover, this subcluster shows two patterns as shown on Figure 3. One, which consists of five stands (1,10,8,9 and 50) is dominated by Juniperus procera and Olea europaea subsp. cuspidata trees. The remaining four stands (12,49,51 and 54) are differentiated by the dominance of Erica arborea shrubs. However, there is no major difference in physical and chemical characteristics of the soil in both areas. But the Ericaceous vegetation dominate in the areas where rock outcrop is abundant and stony side slope.

This community (subcluster a) in general occupies the east-facing slopes. In this community, there are exotic trees such as, Cuppressus sp. in the dry river valleys, parts of ridge top and some hillside slopes. These introduced species, grow in pure stands, the ground layer is mostly bare, that is, they do not allow the growth of other plants. Compared to the dominant indigenous species in the area, the Cuppressus species are seen falling easily due to the shallower depth of the soil and steep slopes, which could not hold them tight (similar event was observed by Ferede, 1984 on Mount Ziquala). Compared to the recently introduced Cuppressus species, the indigenous species grow in association with various species of grasses, herbaceous species, mosses and abundant newly appearing seedlings of Juniperus procera and Erica arborea, which suggest the remarkable regenerating power and adaptability of these indigenous species.

The stands of subcluster b (7,11 and 53) are located on the west facing slopes, which are highly degraded and drier. These are mostly covered by herbaceous vegetation and shrubs, which have regenerated after area closure. The succulent herb, Aeonum leucoblepharum was observed only on this side of the hill. Stand 6 of this subcluster is located on the gentler ridge top, which was previously used as a military camp. The other groups of this subcluster (4 and 5) are found on drier east-facing side slopes. Therefore, subcluster b is dominantly covered by shrubs and herbaceous plants. The main shrubs in this subcluster include, Clutia abyssinica, Rumex nervosus, Lippia adoensis and Indigofera erecta. The major grass species in this subcluster are Panicum pusillum,Hyparrhenia rufa,and Aristida adscensions. The major herbs consist of Aeonum leucoblepharum, Helichrysum odoratisum, Kalanchoe deficiens, Plectranthus rupestis and Polygala rupicola .

4.1.2.2 Euclea schimperi Type (Cluster B)

The major cluster B, which consists of 19 stands (Table 3 and Fig.3), occupies altitudes between 1,700 m to 2,200 m (with the exception of stand 2, which was recorded at an altitude of 2,460 m). It is characterized by evergreen shrubs generally dominated by Euclea schimperi . This community is divided into three subclusters designated as c, d and e, which differ in the most plant composition (the dominant species composition within each subcluster is given below and the whole species composition is listed in Appendix 2). The dominant species of plants throughout the area of these subclusters is similar (Euclea schimperi), but the plants associated with these subclusters vary from one subcluster to another as it can be understood from the following results.

Subcluster `c' is extremely dominated by Hyparrhenia hirta grass (comprising 60) followed by Euclea schimperi and Carisa edulis shrubs. This subcluster is located on higher altitude (2192 m) as compared to the other two subclusters (d and e).

Subcluster `d' is characterized by high cover of shrubs such as Euclea schimperi , Dodonaea angustifolia,Cadia perpurea,Calpurnia aurea, Rhus natalensis and Diospyros abyssinica . Most of the ground layer is densely covered by the herb Hypoestus forskalei. There is no dominant grass in this subcluster.

Subcluster `e' is dominated by the species of Panicum and Hyparrhenia grasses followed by the abundant shrubs such as Myrsine africana , Euclea schimperi , Jasminum grandiflorum , Dodonaea angustifolia and Pterolobium stellatum. The Hypoestus forskalei is abundant in the ground layer.

4.1.2.3 Acacia asak Type (Cluster C)

This group of vegetation is found at the foot of the escarpment below Bati town at Fura farmers' association between 1,200 m to 1,500 m altitudes. This community type is characterized by smaller shrubs, succulents and scattered trees which are important for shade. Acacia asak is generally the dominant shrub in the area associated with other plants. The area of this community (cluster) is drier. Large area is covered by shrubs and the cultivated land is generally small as compared to the former two clusters. There are four subclusters in this community designated as f, g, h and i (the dominant species of plants in each of the subclusters is summarized below and the whole species list is given in Appendix 2).

Subcluster `f' is dominantly covered by shrubs consisting of Acacia asak and Cladostigma dioicum and the succulent Sanseviera ehrenbergii . The ground layer of this subcluster is mostly bare and stony.

Subcluster `g' is dominated by the grass Hyparrhenia rufa followed by the shrub Acacia asak. Shrubs such as Acalypha fruiticosa , Ximenia americana and the succulent Sansevieria ehrenbergii are abundantly distributed in this subcluster. The ground layer is bare and stony.

Subcluster `h' as a whole is dominated by Acacia asak shrub with the abundant cover of the annual herb Satureja punctata. The grass covering the field layer of this subcluster were dry during the field work and were difficult to be identified.

Subcluster `i' is dominated by the succulent climber Cissus rotundifolia followed by the shrub Acalypha fruiticosa. The other shrubs such as Cadia perpurea, Acacia asak Grewia velutina, Ximenia americana and the succulent Cissus guadrangularis and Sanseviera ehrenbergii are abundant in this subcluster. The dominant herb in this area is Aerva jeivanica. Grasses which are extremely overgrazed and difficult to make identification, dominate the ground layer of this subcluster.

4.1.3. Soils and other Environmental Factors

The result of the laboratory analysis of the soil and the field records of other environmental factors such as altitude, slope, soil depth, textural fractions, soil colour, surface stoniness, etc. for each of the major clusters and subclusters were averaged and summarized in Tables 4 and 5. In order to see whether there is significant variation in edaphic factors, altitude and slope among the three major clusters and the nine subclusters, one way analysis of variance (ANOVA) was calculated for soil depth, pH, total nitrogen, organic carbon, available phosphorus, conductivity, textural fractions, altitude and slope. This was followed by the Duncan's/ Neuman-Keuls multiple comparison analysis to show variations in pairs of clusters and subclusters. The results of the multiple comparison show that altitude sand, silt and organic carbon significantly vary among the three major clusters. Because of the limited number of laboratory analysis done for exchangeable cations for all clusters, it has not been possible to conduct more regorous statistical analysis and hence were compared using only mean value (see Appendix 5) and the findings suggest that there is no major difference in exchangeable cations among all clusters and subclusters.

Table 4. Duncan's /Neuman-Keuls Multiple Comparison Results for mean values of three Major Clusters at $P < 0.05$.

Clusters	A	B	C
Altitude(m)	2611 x	1950 y	1313 z
Slope(%)	57.8 x	52.0 x	37.0 y
pH	6.7 x	7.2 xy	7.7 y
EC(mmhos)	0.065 ns	0.072 ns	0.09 ns
Sand(%)	47.2 x	55.5 y	65.8 z
Silt(%)	37.7 x	29.9 y	23.2 z
Clay(%)	15.2 x	14.3 x	11.0 y
Soil depth(cm)	25.5 x	17.3 y	15.8 y
Total nitrogen(%)	0.353 x	0.255 xy	0.158 y
Organic carbon(%)	4.5 x	2.9 y	1.7 z
Available phosphorus(ppm)	17.9 x	4.4 y	2.6 y

* - Similar letters in each row indicate that there is no significant difference between variables and different letters indicate significant differences (at $p < 0.05$).

ns= no significant difference

Tables 5. <u>Duncan's /Neuman - Keuls Multiple Comparison Results for Nine subclusters</u>

Subclusters	a	b
Altitude(m)	2596 ns	2635 ns
Slope(%)	67.1 ns	46.5 ns
pH	6.7 ns	6.7 ns
EC(mmhos)	0.06 ns	0.08 ns
Sand(%)	45.1 ns	49.7 ns
Silt(%)	39.1 ns	35.7 ns
Clay(%)	15.8 ns	14.7 ns
Soil depth(cm)	25.2 ns	25.9 ns
Total nitrogen(%)	0.40 ns	0.34 ns
Organic carbon(%)	5.0 ns	4.3 ns
Available phosphorus(ppm)	10.1 ns	22.97 ns

Note: Numbers are mean values

ns= not significant

Table 5. <u>Continued</u>

Subclusters	c	d	e
Altitude(m)	2192 x	1850 y	2023 z
Slope(%)	68.0 ns	49.6 ns	47.3 ns
pH	6.8 ns	7.3 ns	7.2 ns
EC(mmhos)	0.05 ns	0.08 ns	0.08 ns
Sand(%)	59.8 ns	54.7 ns	53.0 ns
Silt(%)	29.3 ns	30.3 ns	29.3 ns
Clay(%)	11.25 ns	15.00 ns	15.67 ns
Soil depth(cm)	13.8 ns	19.1 ns	15.2 ns
Total nitrogen(%)	0.217 x	0.23 x	0.41 z
Organic carbon(%)	2.27 x	2.74 x	4.61 z
Available phosphorus(ppm)	2.88 ns	4.98 ns	4.19 ns

Note: Numbers are mean values
Similar letters indicate that there is no significant difference between variables and vice versa.
ns= not significant

Table 5. Continued

Subclusters	f	g	h	i
Altitude(m)	1310 x	1315 x	1380 y	1280 x
Slope(%)	43 x	48 xy	31 x	15 xz
pH	7.71 ns	7.70 ns	7.95 ns	7.72 ns
EC(mmhos)	0.08 ns	0.09 ns	0.10 ns	0.10 ns
Sand(%)	65.4 ns	65.0 ns	69.0 ns	66.0 ns
Silt(%)	22.4 ns	24.3 ns	22.0 ns	23.0 ns
Clay(%)	12.2 ns	10.7 ns	9.0 ns	11.0 ns
Soil depth(cm)	14.9 ns	16.9 ns	17.3 ns	15.1 ns
Total nitrogen(%)	0.15 ns	0.17 ns	0.119 ns	0.17 ns
Organic carbon(%)	1.5 ns	1.9 ns	1.2 ns	1.6 ns
Available phosphorus(ppm)	2.1 ns	2.8 ns	1.4 ns	3.6 ns

Note: Numbers are mean values

Similar letters indicate that there is no significant differences between variables and vice versa

ns= not significant

4. 2 Discussion

4.2.1 Interaction between Vegetation and Environmental Factors

4.2.1.1 Comparison of Clusters in Relation to Altitude

The study area extends from 1,200 m altitudes at the foot of the rift escarpment to 2,800 m altitude at Sulula area (northeast of Desse town). The vegetation studied on the escarpment at different altitudes is categorized into three major clusters (groups) A, B, C and nine subclusters, a, b, c, d, e, f, g, h and i as indicated in section 4.1 (Fig. 3). The pattern of the grouping (distribution) of the vegetation showed very strong variation with altitude. The vegetation grouped under cluster 'A' occupied the higher altitude (2,500 m to 2,800 m); while those in clusters (groups) `B' the medium altitude (1,700 m to 2,200 m) and 'C' the lower altitude (1,200m to 1,500m). The analysis of variance for altitude among three major clusters revealed very high and significant variation of vegetation with altitude. The result of the analysis of multiple comparison between pair of clusters (Table 4) also shows that three clusters significantly vary from one another with altitude (at $P<0.05$). Since altitude affects the climate, soil characteristics and depth, exposure to wind, etc in a given area, it would have influence on the occurrence and distribution of plants (Robinson, 1972: 184). The rainfall records in the area show that the total amount of annual rainfall in the area of cluster A is higher, but decreases towards cluster C lying in the lower altitude (Table 1). Moreover, in the higher altitudes, soil moisture is reliable for plant growth for months of July to October in the main rainy season and for April during the spring season (Daniel, 1987: 55). Therefore, the amount of moisture, which is related to altitudinal gradient is also very important for the differentiation of vegetation types and characteristics into different categories in the study area.

Slope is another important factor which is related to vegetation. It influences the plant life via the soil characteristics and drainage (Robinson, 1972: 184). In the present study, all the samples of vegetation were taken from hillside slopes and therefore, the slope throughout the study area is mostly steep. The result of the multiple comparison (Table 5) show that there is no significant variation in altitude and slope between subclusters `a' and `b' (subdivisions of major cluster A).

In cluster B, the three subclusters c, d and e are differentiated on the basis of altitude, which vary significantly between pairs of subclusters. Accordingly, subcluster `c' is found relatively on higher altitude (2192 m) followed by `e' (2023 m) and d (1850 m) respectively. However, there is no significant variation of slope between three pairs of clusters (see Table 5).

Amongst the subclusters of major cluster C, located in the lower altitudes (f, g, h and i), the significant contrast in altitude is observed only between subcluster `h' and the rest of the three subclusters. There is no significant variation in altitude between subclusters `f', `g' and `i'. However, the mean values of altitude for the four subclusters slightly vary from one another (1310 m, 1315 m, 1380, and 1280 in `f', `g', `h' and `i' respectively) though the variation is not statistically significant. There is also no significant variation in slope except between subcluster `i' and `g' (Table 5). Moreover, all the four subclusters are characterized by the abundant rocks on the ground layer probably due to high temperature.

4.2.1.1.2 Comparison of Clusters in Relation to Physical Characterstics of the Soil

The physical characteristics of the soil determine the soil's capacity to provide plants with air, water and rooting media. Important physical factors of the soil showed significant contrast among different clusters. The depth of the soil in all clusters is shallow suggesting the steepness of the slope. However, it is variable with altitude. As a result, cluster A on the higher altitude (Juniperus procera dominated vegetation) is characterized by relatively thicker soil depth (25.5cm), very dark brown to black soil colour (7.5YR2.5/3,10YR3/2 to 10YR 2/1) and loamy to silt loam soil texture (Appendix 3). Soil colour is related to organic matter content of the soil, climate, soil drainage and soil mineralogy (Thompson and Troeh, 1978). Therefore, relatively higher organic matter content of the soil and better moisture in the area of cluster A could have influenced the colour of the soil. The result of the analysis of multiple comparison between pairs of clusters showed significant contrast in soil depth between clusters A and the other two clusters (B and C). There was no significant difference in soil depth between clusters B and C, which are found in the middle and lower altitudes (See Table 4). Textural fractions also showed significant variation among all the three major clusters, except clay which differ significantly only between clusters A and C and B and C. Accordingly, the silt content showed relatively higher concentration (35%) in cluster A, on higher altitudes and decreases towards the lower altitudes. Whereas the percentage sand content is relatively lower (47%) in cluster A and increases towards lower altitudes (in the area of clusters B and C) (See Table 3).

The soil depth in the area of cluster B, (Euclea schimperi dominated vegetation) in medium altitude is lower (17.3cm) compared to cluster A, and the textural fractions of the soil vary from silt loam to loam. In this cluster, the sand content increases to 55.5% and the silt content decreases to 29.9% and both significantly vary from A as the result of the multiple comparison show (Table 4). Both clusters A and B are characterized by almost similar clay content. The colour of the soil in cluster B on average is dark brown (7,5YR $^{3}/2$). This implies the decreasing moisture and organic matter content of the soil which have influence on soil colour.

The depth of the soil in cluster C (Acacia asak dominated) vegetation, is shallower and does not significantly vary from cluster B. The significant variation in soil depth is observed between cluster C and A. The texture of the soil in cluster C is fully sandy loam and extremely gravely implying the higher weathering in this area. The result of the analysis of multiple comparison (Table 4) between pair of clusters show significant variation of textural fractions between clusters C and the rest two clusters which are found on medium and higher altitudes respectively. Accordingly, cluster C is characterized on average by higher percentage of sand (65.8%) lower silt and clay contents (23.2% and 11.0%), respectively. The colour of the soil in cluster C is lighter that is,it ranges from brown to darkbrown (7.5 YR 3/4 to 7.5YR 5/4) than the rest two clusters. This implies the low organic matter content in the soil which influences the colour of the soil. In addition to low organic matter content of the soil, the disintegration of the rocks from the surface layer might have influenced the textural fractions of the soil. Relatively sparse vegetation cover, bare ground layer and lower moisture may also be one of the factors for the low organic matter addition to the soil layer. The percentage surface cover of stones (Table 4 and Appendix 4) decreases with altitude, that is, the surface stoniness increase from higher (4.6%) in cluster A, towards the lower altitudes (9.5% and 29.5%) in clusters B and C, respectively.

All the physical factors considered in this study did not show any significant variation between subclusters a and b. These two subclusters differ only in vegetation composition. However, the mean values in Table 5 show slight difference in the means of sand and silt fractions, which vary from 45% and 39.1% in a to 49.7% and 35.7% in b. Therefore, the physical factors of the soil did not show any relationship with the variation of vegetation types. The variation of these subclusters in the dominant plants is probably due to the previous human impact, which is discussed under section 4.2.1.1.3 below and the uniform slope in the area.

There is no significant differences in physical factors of the soil between pairs of subclusters `c', `d' and `e' (Table 5). But they differ from one another in the dominant plants, that is, subcluster c and e are dominated by grass species in the genera of

(Hyparrhenia and Panicum) and subcluster `d' is dominated by Euclea schimperi and other shrubs. Therefore, the variation of vegetation does not have any relation with variation in physical factors of the soil in this particular case. However, the significant variation in altitude, soil chemical characteristics, particularly, organic matter and total nitrogen and the micro_environmental location of these subclusters might be attributed to these subdivisions.

The result of the statistical analysis and mean values (in Table 5) show that there is no significant variation of physical factors of the soil for subclusters `f', `g', `h' and `i'. But these subclusters show variation in some of the major dominant species. Most of these subclusters are commonly characterized by uniform slopes, bare and stony ground layers. Therefore, the variation of dominant plants among the subclusters might be attributed to `competitive_exclusion principle'(Beals, 1969), micro_level variation of soil moisture and related factors.

4.2.1.1. 3 Comparison of Clusters in Relation to Chemical Characteristics of the soil

The Chemical characteristics determine the soil's capacity to provide sufficient and a balanced supply of nutrients to plants. Some of the chemical elements investigated show variations among three major clusters.

One of the chemical elements related with plant growth is soil pH. It influences the growth of plants indirectly except in cases of extreme acidity or alkalinity. The pH influences the rate of plant nutrient release by weathering, the solubility of all materials in the soil and the amounts of nutrient ions stored on the cation exchange sites (Lenon and Cleaves, 1983: 35; Thompson and Troeh, 1978). However, the result of multiple comparison between pairs of clusters shows that only clusters A and C show significant contrast in soil pH. Moreover, the mean values in Table 4 show that the pH values for the clusters on higher and medium altitudes (A and B) are neutral while they are alkaline in the lower altitudes in cluster C.

There is no significant variation in electrical conductivity among all clusters implying that the soils throughout the study area are free from salinity (see Thompson and Troeh, 1978).

Nitrogen is an important chemical element for plant growth. The mean values of the total nitrogen for the three major clusters (Table 4) show an increasing trend from cluster C at lower altitudes to cluster A at higher altitudes. However, the result of multiple comparison between pairs of clusters shows a significant variation of total nitrogen only between clusters A and C. There is no significant contrast in total nitrogen between clusters A and B and B and C. This may be due to transitional nature of cluster B between clusters A and C. Moreover, interms of the ratings of Landon (1991) as cited in Belay (in press: 7), the percentage of total nitrogen in the soil among three major clusters is medium (see the ratings in Table 6 below). Therefore, the total nitrogen is also related with high organic matter in the higher altitudes (see Scholes,et.al., 1994).

Table 6. Broad Ratings of Properties that are Most Critical to Soil Fertility

Property	Low	Medium	High
CEC (Meq/100gm soil)	<15	15-25	>25
Base Saturation (%)	<20	20-60	>60
Exch. cations (Meq/100gm soil)			
K	<0.2	0.2-0.5	>0.5
Mg	<0.5	0.5-4	>4.0
EPP	<2	-	>25
Organic C (%)	<4	4-10	>10
Total N (%)	<0.2	0.2-0.5	>0.5
Available p (ppm)	<5	5-15	>15

Source: Landon (1991) cited in Belay (in press: 7)

The arrangement of major clusters on the basis of descending altitudinal order of the organic carbon gives the order A, B and C implying the change of major clusters in the organic carbon content with altitude (4.5%, 2.9% to 1.7%) in clusters A, B and C respectively (see Table 4). The result of the multiple comparison of organic carbon for the pairs of the clusters showed the wide variation of organic carbon between all pairs of clusters. The Landon's ratings in Table 6 also shows that cluster A is characterized by medium content of organic carbon and it is categorized as low in clusters B and C. This also suggests that the organic matter is relatively high in the high altitude. That is, cluster A and decreases towards clusters B and C, which occur at medium and lower altitudes. A similar situation was observed by Beals (1969) and Lisane Work Nigatu (1984) in Harena forest. Organic matter is an essential source of nutrients for plants. It influences the physical and chemical properties of soils, increases the water holding capacity of the soil, etc., (Buckman and Brady, 1969: 25; Scholes, et.al, 1994: 130). Therefore, the organic matter has the significant relation with the variation of vegetation. The high amount of organic matter in the high altitude (cluster A) may be due to decrease in temperature and higher moisture. The high moisture and lower temperature in the area of cluster A might have also contributed to high soil organic matter accumulation and lesser decomposition. The fine texture of the soil and humus as indicated by higher organic carbon content (Menassie and Masresha, 1996) also implies the high moisture retention capacity of the soil in the higher altitudes.

The mean values in Table 4 show that the available phosphorus in the soil decreases with altitude, that is, it is high in cluster A, (17.9 ppm) and low in clusters B and C (4.5 and 2.63 ppm), respectively. The result of the analysis of multiple comparison of available phosphorus for pairs of clusters showed significant contrast between clusters A and B and A and C (Table 4). The two clusters in the medium and lower altitudes (B and C) did not show any significant variation in available phosphorus. Generally, cluster A is characterized by high amount of available phosphorus and clusters B and C contain low amount of available phosphorus. The phosphorus content of the soil is related to the organic matter content of the soil, pH, climate,etc.(Thompson and

Troeh, 1978). Therefore, the high amount of available phosphorus in the high altitude could be attributed to the increase in organic matter.

As the mean values (Appendix 5) show, it seems that there is no major differences in exchangeable cations in the area of the different clusters and subclusters. However, the rating in Table 6 show that cluster C in the lower altitudes is characterized by low exchangeable potassium content in the soil, but clusters B and A in the medium and higher altitudes are characterized by medium content of potassium. Magnesium, in the area of all clusters is rated as high. Calcium is more prevalent throughout the study area than other cations. This is due to relatively fast rate of release and it is absorbed by the clay and humus micelles more strongly than any of the other basic cations (Thompson and Troeh, 1978). This shows that throughout the study area, the distribution of exchangeable cations is mostly similar, that is, their variation with vegetation types and altitude is less. This may be attributed to the uniformity of the parent material, which is volcanic basalt of similar age and composition (Beals, 1969 see also Weinert and Masurek , 1984 in Zerihun, 1985).

The mean values of the chemical analysis and the result of multiple comparison between pair of subclusters (Table 5) show that there is no significant difference in chemical characteristics of the soil between subclusters a and b. The mean values of exchangeable cations (Appendix 5) are also almost similar. Therefore, generally, it can be argued that both physical and chemical characteristics of the soil in both subclusters do not show variation. The variation of vegetation in the different subclusters may be due to human interference. Subcluster `a' has been protected for longer period from human interference due to its proximity to a church and covered with dense forest vegetation. Subcluster `b', however, has been regenerating after program of area closure and therefore, dominated with shrubs and herbaceous vegetation (see section 4.1).

As stated earlier, cluster B is divided into subclusters 'c', 'd' and 'e'. These subclusters are arranged according to descending altitude as 'c', 'e' and 'd' (2192 m, 2023 m and 1850 m), respectively. Mean values and the result of multiple comparison between pairs of clusters (Table 5) show that subcluster `e' showed significant contrast in organic carbon and total nitrogen from subclusters `c' and `d' (Table 5). Subclusters `c' and d did not show any variation in chemical elements of the soil. The rest of the chemical factors are almost similar among three subclusters except slight variation in mean values. Beside altitude, the variation of the dominant plant species among these subclusters might be related to the micro_environmental location of these subclusters. Subcluster `c' is located on drier backslopes and uniformly covered by Hyparrhenia grasses. Subcluster `d' is located on footslopes and shoulder with commonly bare ground layer. Where as subcluster `e' is located along the dry river valleys. Therefore, the dense cover of ground layer by Panicum grasses and other herbs might have contributed to higher organic matter and total nitrogen in subcluster 'e'.

There is no statistically significant variations in any of the chemical elements of the soil in cluster C between pairs of subclusters `f', `g', `h' and `i' (Table 5). But as shown in Table 5 and Appendix 5, subcluster `h', which is found at higher altitude as compared to the other three subclusters (f, g and i), is relatively lower in the mean values of the chemical elements of the soil. In general term, there is no variation in chemical elements of the soil with variation of vegetation type at this micro-environmental perspective.

From the above discussions it can be argued that physical and chemical characteristics of the soil do not have any significant relation with in the local level variation of vegetation. Here, the factors such as inter and intraspecific competition between plants caused by their adaptation to similar environment and related factors should be considered (see Uhlig, 1990, Beals, 1969). Moreover, the uniformly steep slopes within each zone might have played role for the uniformity of environmental factors among all subclusters.

4.2.2 Comparison of the Clusters on the Basis of the Diversity of species

The result of the computer program Shannon (by Zerihun Woldu, 1989) showed that the species richness and relative abundance (diversity of species) decreases with decreasing elevation. Accordingly, the richness of vegetation interms of species composition decreases from the area of cluster A on the higher altitudes, where moisture is higher and edaphic factors are relatively better, towards the lower altitudes (clusters B and C), where the essential factors for plant growth particularly, moisture is relatively scarce (Table 7). Therefore, both trees and herbaceous vegetation decrease with altitude. Lower altitudes (cluster C) are found to be abundantly covered with smaller shrubs and scattered trees one gentler slopes and valley sides. Moreover, abundant succulents imply the shortage of moisture in the lower altitudes.

Table 7. Shanon-Weiver Diversity Index

Clusters	No. of Species	Column Total	* H'	H' MAX	H'/HMAX
A	90	175	3.569	4.5	0.904
B	68	120	2.905	4.2	0.836
C	47	92	2.569	3.85	0.858

$* H = -\sum_{i=1}^{s} p_i \ln p_i$

Where, H= Diversity,

s= the number of species,

pi= the proportion of individuals or the abundance of the i^{th} species expressed as a proportion of total cover.

H`MAX= Diversity assuming all the constituent species are evenly distributed.

H'/HMAX= Evenness

ln= $\log^{\text{base } n}$

As is clearly shown in Table 7, the H values (diversity index) decreases from cluster A to C. Diversity is the measure of species richness (the number of species present) and evenness (the relative abundance of the species)(Duffey, 1974), both of which are relatively higher in the higher altitudes (Cluster A). This may be due to the favourable conditions (especially of high moisture) in the area of cluster A, which allowed the growth of diverse species of plants ranging from herbaceous to woody ones. The number of different species of plants decrease towards the lower altitudes. In the lower altitudes, climatic conditions (temperature) become harsh and moisture is the serious problem for plant growth. As a result, in cluster C in the lower altitudes, the ground layer is mostly bare, stony and covered with some succulent (Cissus rotundifolia, Cissus quadrangularis, Sansevieria ehrenbergii, etc.) species suggesting the severe scarcity of moisture and higher temperature in the area.

4.2.3 Aspects of Human Influence on Vegetation At Different Altitudes

As indicated earlier, in the area of cluster A, soil moisture and some of the edaphic factors are better, the diversity of vegetation in species composition is highest. This area is relatively protected both from human and cattle interferences by armed men assigned by the government because this is the only remaining patch of vegetation in the area. Observation during fieldwork and discussion with some of the farmers in the surrounding area of this vegetation group show that due to the shortage of cultivable land , grazing lands and shortage of fuelwood, the local people are forced to poach trees and graze their animals illegally.

In the area of cluster B (medium altitudes), the vegetation covers relatively a wider area though there is expansion of cultivation. The control of vegetation from destruction is not as strict as in that of areas of cluster A. The major problem here is the production of charcoal for market and many of such events were observed in the vicinity of the study plots during the field work.

As observed during fieldwork, the area of cluster C is drier and the vegetation covers dominated by shrubs cover a wider area. The cultivated land, which is smaller compared to the areas of former two clusters, is restricted to river valleys. The result of this study showed that Acacia asak is the dominant and widely distributed species in this area. It is also a very important species as fodder for browsing animals such as camels and goats, for charcoal making and for fuel wood for both domestic consumption and market. Therefore, this species is extremely over utilized and as a result very much reduced interms of its areal coverage. The absence of rule to control over any one who wants to clear any part of the wood land (Sebsebe, in press: 17), aggravated this situation. As a result, it is common to see many camels loaded with fuelwood and charcoal every morning on the way to Bati market. This is considered as important source of cash in the area. This increases during the drought period to get cash(Sebsebe, in press) (this event was also observed during field work).

5. Conclusion and Recommendation

The study of vegetation and environmental factors in the eastern parts of South Welo based on three altitudinal zones (at 1200 m-1500 m (Bati area), 1,700 m-2,200 m (Degan area) and 2,400 m-2,800 m (Sulula/Desse area) showed that the vegetation in the study area could be divided into three major clusters and nine subclusters. The distribution of the different clusters (groups) of vegetation showed very strong variation with altitude and resulting climatic characterstics. This shows that altitude through its influence on other environmental factors particularly on moisture,soil characterstics and depth,etc. has brought the variation in type and distribution of vegetation in the study area. As the result of this,the type and density of vegetation showed variation with altitude and related environmental factors.

Cluster' A 'with two subclusters (a and b) occuring at higher altitudes is characterized mainly by the Juniperus procera, Erica arborea, Olea europaea subsp. cuspidata and other trees, shrubs and herbs in subcluster a. This vegetation represent the dry evergreen forest vegetation in the area. Epiphytic plants, particularly, mosses are more prevalent in the ground layer and tree trunks in this group of vegetation implying high moisture in the area. The community in cluster' A' is also characterized by high species diversity as compared to the other two clusters (groups). This is due to increased moisture on the higher altitudes. The general area in this cluster is on steep slopes and , the soil is characterized by relatively deeper soil, loamy to silt loam texture and higher content of organic matter, high total nitrogen and available phosphorus compared to the rest two clusters. This association is primarily due to the influence of altitude and/or climate despite the steep slope where the soil is normally expected to be shallower than the two other clusters. In many areas of cluster' A', these species of plants have been cut down extensively for several decades and mature trees are currently very rare except in the compounds of old churches. As was also observed during field study, many Olive trees were ringed by the local people and Erica arborea shrubs and Juniperus procera trees were found destroyed. Therefore, there is a conflict of interest between the needs of the local people in using these resources and the government policy imposed to protect it. This contradiction may threaten the sustainability of the vegetation. Subcluster b in cluster A represent the secondary vegetation, which is mostly dominated by shrubs, grasses and herbs such as Clutia abyssinica, Rumex nervosus, Panicum pusillum, Hyparrhenia rufa, Helichrysum odoratisum, Kalanchoe deficience,etc. This also indicates the effect of human influence on vegetation this area. The degraded areas in the major cluster A are planted with exotic species particularily with Cuppreus sp. These introduced species do not allow the growth of other plants and the ground layer in them is mostly bare. Moreover, these exotic species easily fall when mature due to shallower soil depth , steep slope and their bigger sizes. Therefore, the replantation of degraded areas with indigenous species should be given a high priority. However, since the final result of conservation is to satisfy the needs of local people in protecting the environment, the selective cutting and collection of dead woods should be allowed to the local people. Such policy motivates the local people to participate in the conservation work (see Berkmuller, 1992:143).

Cluster 'B'with three subclusters (c, d, and e) is mainly dominated by Euclea schimperi shrubs. Like the first category of vegetation,(cluster A) it is dominantly evergreen, but unlike the first category, the vegetation here mostly consist of shrubs. Most of the environmental factors especially altitude,clay fractions of the soil, depth of the soil, organic carbon and available phosphorus showed significant decline from cluster A. Agricultural expansion and coal production and ineffective protective activity is a major problem to this group of vegetation. Therefore, given the steepness of the slope and dry climatic conditions, the ecological balance may be disturbed, if this condition is allowed to continue further. Thus, it is recommended that tree cutting and agricultural expansion in these fragile slopes should be minimized and these areas should be used mostly for grazing (controlled grazing).

Cluster 'C'with four subclusters (f, g, h, and i), which occurs at the lower altitudinal zone is dominated by shrubs particularly, Acacia asak with scattered big trees such as Acacia tortilis ,Berchemia discolor, Boscia coriaceae, etc. This area is more arid compared to former two clusters (groups) and it is exposed to frequent drought. The ground layer is very dry and mostly bare and stony. Most of the physical and chemical characteristics of the soil showed significant variation from clusters A and B. Soil in this area is largely sandy and full of gravels. This area is therefore, very fragile and once vegetation is depleted, regeneration may be very difficult given the unfavourable climatic conditions. Therefore, it is recommended that the current act of free cutting of vegetation, especially coal preparation and fuel wood collection for market should be minimized.

In general, this study showed that vegetation in the study area vary from dense-tree dominated vegetation in the higher altitudes towards shrub-dominated sparse vegetation in the lower implying the influence of environmental factors on the distribution of vegetation.

It is also observed from this study that each major group of vegetation (clusters) is divided into different subgroups locally. However, the result of the statistical analysis showed that there is no significant variation in physical and chemical characteristics of the soils treated between pairs of subclusters in each area.

Finally, for the whole study area, it is recommended that the conservation work should be practiced through the full participation of the mass so that the protection of vegetation resources cannot be viewed as the duty and responsibility of the government alone. This should be done through the discussion with the local people about the adverse effects of the devegetation on the environment and the people as well. This enhances the awareness of the local people on the sustainable use of the natural resources in the area.

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Appendix 1

List of Plant Specimens Collected from southern Welo

Coll. No.	Local name and Language	Scientific Name and Family
039	Nech Girar(Amh).	Acacia abyssinica, Hochst. ex Berth (T) (LEGUMINOSAE)
083	Sabansa(Or.)	Acacia asak (Forsk.) Willd (S) (LEGUMINOSAE)
129	Dodoti Girar (Amh.)	Acacia etbaica Schwent subsp. unicinta Brenan (T) (LEGUMINOSAE)
088	Karora (Or/Amh.)	Acacia tortilis (Forsk) Hafine (T) (LEGUMINOSAE)
091	Irgi (Or.)	Acalypha fruiticosa (Forsk.) (S) (EUPHORBIACEAE)
074	Kiraro (Or.)	Acokanthera schimperi (Forsk.) Brenan(T/S) (APOCYNACEAE)
098	Aredo (Or.)	Actinopteris dimorph Pic. Serm (F) (ACTINOPTERTDACEAE)
106	Ejersan Gabe (Or.)	Adenia Venenata(S) (PASSIFLORACEAE)
058	Yefiyel joro (Amh.)	Aeonum leucoblepharum (Webb.ex. A.) (H) (CRASSULACEAE)
096	Chichuwe (Ishute/Or.)	Aerva jeivanica (Brum.f) Juss (H) (AMARANTHACEAE)
011	Eret (Amh.)	Aloe debrana christian (H) (ALOACEAE)

(T)= Tree, (H)= Herb, (G)= Grass, (F)= Fern, (S)= Shrub, (Cli.s)= Climbing shrub Or.= Oromigna * Family names are in the Brackets. Amh.=Amharic

043	Kuman (Amh.)	Anethum foeniculum (H) (APIACEAE)
024	Nech Sar (Amh.)	Aristida adscensionsis L. (G) (POACEAE)
015	Yeset Kest (Amh.)	Asparagus falctus L.Var. ternifolius (Bak.) Jessop (Cli.S) (ASPARAGACEAE)
040	-	Asplenium aethiopicum (Burm.f.) Becherer (H) (ASPLENIACEAE)
089	Bedeno (Amh.)	Balanites aegyptiaca (L.) Del.(S) (LEGUMINOSAE)
032	-	Barleria boranensis Fiori (cli.H). (ACANATHACEAE)
073	Yeset af/Yesefet(Am/Or.)	Barleria Prionites L. Subsp. induta (C.B.cl.) Brummitt & J.R.I Wood. (H) (ACANTHACEAE)
131	Gewo (Amh.)	Berberis Holstii (Engl.) (S) (BEREBERIDACEAE)
094	Jejeba (Or.)	Berchemia discolor (Klotzsch) Hemsl (T) (RHAMANACEAE)
051	Azamir (Amh.)	Bersama abyssinica Fresen (T) (MELIANTHACEAE)
105	Kokalsha (Or.)	Boscia coriaceae Pox (T) (CAPPARIADACEAE)
071	Hinjiro/Or.)	Cadia Perpurea (Picc.) Ait (S) (LEGUMINOSAE)
003	Digitta (Amh)	Calpurnia aurea (Ait.) Benth (S) (LEGUMINOSAE)
047	-	Calyusia abyssinica (H) (RESEDACEAE)

(T)= Tree, (H)= Herb, (G)= Grass, (F)= Fern, (S)= Shrub, (Cli.s)= Climbing shrub

124	Kolkolcho (Amh.)	Caralluma sp. (H) (ASCLEPIADACEAE)
004	Hagam (Amh.)	Carisa edulis (Forsk.) vahl (S) (APOCYNACEAE)
111	Tero (Amh.)	Cissus populnea Guill. & Perr (C) (VITACEAE)
084	Murmur/jegu (Or.)	Cissus quadrangularis L. (Sv.) (VITACEAE)
082	Chobi (Or.)	Cissus rotundifolia (Forsk.) Vahl. (Sv.) (VITACEAE)
081	Kemete (Or.)	Cladostigma diocum Redlk. (S) (CONVOLUCLACEAE)
014	Yeazo Hareg (Amh.)	Clematis simensis Fresen (Cli) (RANUNCULACEAE)
134	Messirch (Amh.)	Cleradendrum myricoides Hochst. R.Br. ex vatke (S) (VERBENACEAE)
022	Fiyel-Fej (Amh.)	Clutia abyssinica Jaub. ex Spach.(S) (EUPHORBIACEAE)
61	Dowadowate (Amh.)	Colutea abyssinica Kunth & Bouch.(S) (LEGUMINOSAE)
120	Habalo (Amh.)	Combretum molle G.Don (T) (COMBRETACEAE)
119	Yebune (Amh.)	Commicarpus plumbagineus (Cav.) Standl. (Cli.) (NYCTAGINACEAE)
095	Dido (Or.)	Commiphora africana (A.Rich.) Engl. (T) (BURSERACEAE)
076	Hinjiro tegedira (Amh.)	Concocalyx schimperi (A.Rich) (E) (LORANTHACEAE)

090	Lulude Madero/Mentero/Or./Amh.)	Cordia monica Rox b. (S) (BORAGINACEAE)
027	-	Crotalaria lachnocarpoides Engl. (S) (LEGUMINOSAE)
26	Yeferenj tid (Amh.)	Cuppressus arizonica (T) (CUPPRENACEAE)
140	Gicha Sar (Amh.)	Cyperus distans L.f. (H) (CYPERACEAE)
123	Milas golgul chobi (Amh.)	Cyphostemma adenocaule L. (cli.H.) (VITACEAE)
079	Horsamisa/Hadere (Amh.)	Dicrostachys cinera (L.) Wight & Arn. (LEGUMINOSAE)
075	Selewa (Amh.)	Diospyros abyssinica (Hiern) F. White (T) (EBENACEAE)
029	Kitkita (Amh.)	Dodonaea angustifolia L.F. (S) (SAPINDACEAE)
115	Lenkuwata (Amh.)	Dombeya Kirkii mast (S) (STERICULACEAE)
045	Wulkifa (Amh.)	Dombeya torrida (J.F. Gmel) P.Bamps (S) (STERICULACEAE)
050	Koshim (Amh.)	Dovyalis abyssinica (A.Rich) Warb (T) (FLACOURTIACEA)
103	Re'a dida/Or.)	Echidnopsis damanniana Spreng (H) (ASCLEPIADACEAE)
141	Kolo (Amh.)	Echinops longisetus A.Rich. (H) (ASTERACEAE)
25	Kosheshila (Amh.)	Echinops macrochaetus Fresen (H) (COMPOSITAE/ASTERACEA)

99	Worabekala (Or.)	Ecobolium Viride (Forssk) Alston (S) (ACANTHACEAE)
122	Hulaga (Amh(or)	Ehretia cymosa Thonn (T) (BORAGINACEAE)
67	Dedeho (Amh.)	Euclea schimpri (A.Dc.) Dandy (S) (EBENACEAE)
036	Asta (Amh.)	Erica arborea L. (S) (ERICACEAE)
065	-	Eulophia streptopetala Lindl (H) (ORCHIDACEAE)
056	Yeabesha Kulukuwal(Amh.)	Euphorbia ampliphylla pax (T) (EUPHORBIACEAE)
133	-	Euphorbia dumalis (H) (EVPHORBIACEAE)
126	Woin ahiyo (Amh.)	Flueggea virosa (Willd.) Voigt.(S) (EUPHORBIACEAE)
42	Ashket (Amh.)	Galium aparianoides Forsk. (H) (RUBIACEAE)
130	Yebere Chew (Amh.)	Gerbera piloselloides (L.) Cass (H) (ASTERACEAE/COMPOSITAE)
114	Yeayit hareg (Amh.)	Glycine wightii (Wight & Arn) verdc.(Clis.) (LEGUMINOSAE)
044	-	Gomphorcarpus fruiticosus L. Ait.f (H) (ASCLEPIADACEAE)
085	Cheka (Or.)	Grewia tembensis Fresen (S) (TILIACEAE)

069	Hororesa (Amh./Or)	Grewia velutine (Forsk) vahl (S) (TILIACEAE)
86	Hogomodi(or)	Grewia Villosa Willd (S) (TILIACEAE)
109	-	Hibiscus aponeurus sprague & Hutch. (S) (MALVACEAE)
101	Fugna Karam (Or.)	Hibiscus micranthus L.f. (S) (MALVACEAE)
016	Nechilo (Amh.)	Helichrysum odoratissumum (L.) Less (H) (ASTERACEAE)
110	-	Helinus mystacinus (Ait.) Setud. (Cli.H.) (RHAMANALEAE)
135	Yejib Zeng (Amh.)	Heteromorpha trifoliafata (Wendl.) Eckl.Zeyh) (S) (APIACEAE)
023	Key Senbelet (Amh.)	Hyparrhenia hirta (L.) stapf.) (G) (POACEAE)
046	Nech Senebelet(Amh.)	Hyparrhenia rufa (Nees) Stapf. (G) (POACEAE)
021	Tej matebiya (Amh.)	Hypoestus forskalei (Vahl.) Soland-ex Roem & Schultes (H) (ACANTHACEAE)
62	-	Indigofera errecta (S) (LEGUMINOSAE)
013	Tembelel(Amh.)	Jasminum grandiflorum L. (S) (OLEACEAE)
001	Yeabesha tid(Amh.)	Juniperus procera L. (T) (CUPPRENACEAE)

41	Busike (Amh.)	Kalanchoe deficiens (Forsk) Asch & Schwein (H) (CRASSULACEAE)
18	Ashengida (Amh.)	Kniphofia foliosa Hochst. (H) (ASPHODELACEAE)
59	-	*Kowa saar (Amh.) (G)
52	-	Laggera pterodonta (DC.) Oliv. (H) (ASTERACEAE)
010	Alashume (Amh.)	Laggera tometonsa sch. Bip. (H) (ASTERACEAE)
113	-	Lantana viburnoides (Forssk.) Vahl (S) (VERBENACEAE)
063	Yeferes Zeng (Amh.)	Leonotis ocymifolia (Burm f.) I. Warsson var. rainerian (visani) I warson (H) (LAMIACEAE)
093	Deregu (Or)	Lepidagathis scariosa Nees (s) (ACANTHACEAE)
097	-	Leucas discolor sebald (S) (LABIATAE)
138	-	Leucas stachydiformis (H) (LABIATAE)
017	Kese (Amh.)	Lippia adoensis Hochst ex walp. (S) (VERBENACEAE)

(Cli.H)= Climbing Herb.
* = Vernacular name

05	Atat (Amh.)	Maytenus senegalensis (Lam.) Exell (S) (CELASERACEAE)
053	-	Maytenus undata (S) (CELASTERACEA)
48	Yeinchet Shibet (Amh.)	Mosses (E) (BRYOPHYTA)
12	Kerchemo (Amh)	Myrsine africana L. (S) (MYRSINACEAE)
142	-	Nepeta azurea R.Br. ex Benth. (H) (LABIATAE)
030	Askwar (Amh.)	Nuxia congesta R.Br. ex Fresen. (S/T) (LOGANIACEAE)
102	Buna Kamale (Or.)	Ochna inermis Forsk.) schwf. (S) (OCHNACEAE)
137	Dama Kese (Amh.)	Ocimum lamiifolium Hochst. ex Benth (S) (LABIATAE)
128	-	Ocimum stribeyi (S) (LABIATAE)
002	Woira (Amh.)	Olea europaea subsp. cuspidata (L.) Miller (Wall. ex Dc. Cofferi) (T) (OLEACEAE)
049	Manka/Arab kulkuwal(Or.)	Opuntia ficus-indica (Linnaeus) Miller Ryding 1247 (Eth.) (H) (CACTACEAE)

060	-	Osteospermum vailiantii (Decne.) T. Norl. (H) (COMPOSITAE/ASTERACEAE)
035	Keret (Amh.)	Osyris quadripartita (S) (SANTALACEAE)
020	Yekok Sar (Amh.)	Panicum Pusillum Hook (POACEAE)
112	Kefeto (Amh.)	Pavetta oliverana Hiern (S) (RUBIACEAE)
127	Yezinjero Sar (Amh.)	Pennisetum staceam (Forssk.) Chiov (G) (POACEAE)
57	Yewusha Sindedo (Amh.)	Pennisetum sphacelatum (Nees) (G) (POACEAE)
117	-	Pelaragonium alchmilloides L. (H) (GERANIACEAE)
019	Nibasil (Amh.)	Phagnalon abyssinicum Sch. Bip ex A. Rich (H) (ASTERACEAE)
078	Embs tegedira (Amh.)	Phragmanthera macrasolen (E) (LORANTHACEAE)
31	Indod (Amh.)	Phytolacca dodecandra L. Herit (S) (PHYTOLACCACEAE)
108	-	Pittosporum viridiflorum L. (T) (PITTOSPORACEAE)
139	Botter (Amh.)	Plectranthus rupestis (Hochst.)Baker (H) (LABIATAE)
104	Ertu (Or.)	Plicosepalus curviflorus (E) (LORANTHACEAE)

034	Kibe golgul (Amh.)	Polygala rupicola A. Rich. (H) (POLYGALACEAS)
077	Seged (Amh.)	Psydrax schimperian (A.) Rich. (T) (RUBIACEAE)
072	Kentafa (Amh.)	Pterolobium stellatum (Forsk) Brenan (S) (LEGUMINOSAE)
107	Bitane (Or.)	Pupalia lappacea (L.) A. Juss (S) (AMARANTHACEAE)
006	Embs (Amh.)	Rhus glutinosa A. Rich. subsp. abyssinica (Oliv.) Gilb. A. (T)
066	Debebosha (Amh.)	Rhus natalensis Bernh. ex Krauss (ANACARDIACEAE)
068	Tilem (Amh.)	Rhus retinorrhea steud. ex oliver (S) (ANACARDIACEAE)
038	Takima (Amh.)	Rhus vulgaris Meikle forma (S/T) (ANACARDIACEAE)
028	Kega (Amh.)	Rosa abyssinica R.BR. (S) (ROSACEAE)
007	Embonhcho (Amh.)	Rumex nervosus vahl. (S) (POLYGONACEAE)
118	Firtit (Amh.)	Sagretia thea (Osbeck) M.C. Johnston (S) (RHAMANCEAE)
080	Itene (Or.)	Sansevera ehrenbergii schw.ex Bak. (Su.Herb) (AGAVACEAE)
92	Titu (Or).	Sarcostemma viminale (L.) R.Br. (Su.cli.H) (ASCLEPIADACEAE)

033	Yelomi Shita (Amh.)	Satureja abyssinica (Benth.) Briq. (LAMIACEAE)
054	-	Satureja biflora (D.Don) Briq. (H) (LAMIALEAE)
121	-	Satureja Punctata (H) (LAMIACEAE)
064	-	Scabiosa columbaria L. (H) (DIPSACACEAE)
132	-	Sedum alba Forssk (H) (CRASSULACEAE)
116	-	Senecio lyratus Forssk (H) (COMPOSITAE)
55	Chifirig (Amh.)	Sida tenuicarpa volleson (S) (MALVACEAE)
008	Geber emboy (Amh.)	Solanum incanum L. (S) (SOLANALEAE)
037	Tikur emboy (Amh.)	Solanum idicum Linn. S.L (S) (SOLANACEAE)
125.	Semenedid (Amh)	Teclea nobilis Del. S. str. (S) (RUTACEAE)
144.		Tephrosin interrupeta (S) (LEGUMINOSAE)
100.	Birresa /Woiba/ (OR) (Amh.)	Terminalia brownii Fressen (T) (COMBRETACEAE)
136.	Tosign (Amh.)	Thymus schimperi Ronniger (H) (LABIATAE)
009.	Ketatina (Yeahiya joro (Amh)	Verbascum sinaiticum Benth (H) (SCRCOPHULACEAE)

143.	-	Vernonia aurialifera (S) (ASTERACEAE/COMPOSITAE)
087.	Hura (Or.)	Ximenia american L. (S) (OLACACEAE)
070.	Hatukura (Amh.)	Zizyphus mucronata willd. (S) (RHAMANACEAE)

Appenidix 2 *Species composition of the Clusters*

Clusters A

Stand No.	*Species Compostion (collection numbers)*
1	11, 15, 03, 04, 14, 22, 130, 16, 21, 13, 01, 18, 10, 17, 05, 12, 137, 02, 20,19, 139, 34, 06, 07, 55, 08 ,09
10	39, 131, 03, 04, 14, 22, 25, 56, 130, 16, 23, 46, 21, 01,10, 17, 05, 12, 137,02, 35, 20, 57, 19,139, 34, 06, 38, 28, 07, 54, 55, 08
8	11, 15, 04, 134, 26, 29, 130, 109, 21, 13, 01, 63, 05, 137, 02, 49, 35, 20,139, 38, 07, 54
9.	15, 51, 03, 04, 22, 50, 56, 133, 42, 130, 21, 13, 01, 52, 05, 53, 48, 30, 137,02, 20, 19, 108, 139, 38
50.	11, 131, 03, 04, 134, 22, 130, 109, 135, 23, 46, 62, 13, 18, 05, 12, 02, 112,117, 34, 06, 28
12.	40, 22, 36, 65, 130, 114, 18, 17, 05, 48, 12, 30, 139, 06, 28, 07
49.	11, 40, 131, 14, 22, 61, 36, 133, 130, 62, 13, 01, 41, 48, 12, 30, 35, 117, 34, 06, 38, 28, 07, 132
51.	15, 131, 04, 134, 22, 61, 36, 133, 42, 130, 62, 13, 01, 18 ,05 48, 12, 30, 02, 20, 117, 34, 06, 28, 07
54.	131, 22, 26, 36, 133, 42, 16, 01, 18, 17, 05, 48, 12, 30, 02, 35, 34, 06, 38,28, 144, 136
4.	39, 15, 32, 04, 134, 22, 45, 130, 114, 16, 13, 01, 17, 05, 12, 30, 137, 02, 35, 117, 31, 139, 34, 06, 38, 07, 33, 55
6.	24, 22, 26, 44, 43, 16, 01, 17, 05, 12, 02, 19, 139, 34, 06, 28, 07, 55, 09
5.	39, 24, 40, 131, 22, 36, 42, 62, 01, 18, 17, 05, 30, 02, 20, 34, 06, 38, 28,07, 33, 37
7	58, 15, 47, 22, 45, 25, 133, 114, 46, 62, 13, 01, 18, 17, 05, 12, 30, 02, 60, 20, 117, 19, 139, 34, 38, 47, 07, 55

11	58, 40, 22, 61, 114, 16, 46, 21, 01, 41, 59, 63, 17, 05, 12, 60, 20, 117, 19, 139, 34, 07, 64, 09
53	22, 140, 133, 42, 16, 46, 21, 01, 17, 142, 30, 02, 20, 117, 06, 07, 09, 143
3	11, 24, 15, 131, 04, 61, 29, 130, 114, 16, 13, 01, 63, 05, 12, 02, 06, 07, 54, 136
52	15, 03, 22, 140, 133; 42, 16, 23, 46, 01, 138, 30, 137, 117, 31, 139, 07, 08,37

Cluster B

2	11, 24, 27, 26, 23, 05, 12, 02, 28, 07, 55
19	03, 04, 67, 01, 35, 66, 68
20	71, 03, 04, 67, 68
21	39, 11, 04, 67, 35, 06
13	71, 04, 29, 67, 69, 66, 68, 70
14	71, 04, 29, 67, 01, 12, 66
23	71, 03, 29, 67, 49, 66, 68
24	79, 29, 67, 13, 66, 68
15	71, 03, 04, 67, 69, 72, 66
18	74, 71, 75, 76, 29, 67, 12, 72, 66
46	74, 11, 71, 03, 84, 79, 67, 126, 85, 69, 86, 41, 113, 02, 35, 66 125, 126
17	73, 71, 67, 46, 41, 49, 35, 66
44	71, 120, 119, 90, 75, 122, 67, 069, 66, 121
47	11, 73, 71, 75, 29, 67, 85, 69, 86, 46, 21, 13, 20, 117, 121
45	98, 11, 73, 03, 124, 84, 123, 75, 67, 66, 08
48	129, 74, 11, 71, 03, 04, 75, 29, 67, 85, 66
16	39, 29, 67, 21, 12, 35, 20, 66
43	39, 71, 111, 03, 29, 67, 114, 109, 110, 21, 13, 41, 113, 12, 02, 35, 20, 112, 117, 108, 72, 66, 68, 118, 116
22	71, 04, 29, 67, 46, 13, 05, 12, 02, 35, 78, 66

Cluster C

25	83, 106, 84, 82, 81, 85, 86, 80, 92, 87
27	83, 91, 71, 82, 81, 103, 25, 85, 69, 86, 80, 92
29	83, 82, 95, 85, 69, 46, 93, 80, 87
41	83, 91, 98, 96, 105, 82, 81, 99, 69, 93, 87
32	83, 94, 84, 81, 93, 80, 87

30	83, 88, 84, 95, 86, 46, 93, 80, 87
34	83, 98, 71, 122, 85, 101, 46, 08, 87
37	83, 98, 73, 84, 95, 103, 46, 93, 102, 08, 87
36	83, 91, 98, 84, 81, 85, 69, 46, 93, 100, 87
38	83, 98, 73, 84, 81, 95, 103, 69, 86, 101, 23, 46, 41, 93, 80, 87
40	83, 98, 84, 82, 81, 85, 69, 86, 23, 46, 93, 05, 80, 87
42	83, 98, 106, 73, 82, 95, 86, 101, 23, 46, 93, 107, 80, 70
33	83, 96, 84, 82, 95, 93, 05, 100, 87
35	83, 11, 84, 82, 85, 86, 13, 93, 05, 80, 08, 100, 87
26	83, 88, 91, 89, 71, 82, 90, 79, 69, 05, 80
31	83, 88, 91, 84, 82, 90, 46, 66, 80, 87
39	83, 88, 91, 96, 71, 84, 82, 69, 93, 05, 08, 87
28	83, 88, 91, 96, 71, 95, 85, 69, 80, 87

Appendix 3 ***Altitude, slope, soil depth, surface stonness and soil colour of the study area.***

Coll No.	Altitude (m)	Slope (%)	Soil depth (cm)	Surface stoniness(%)	Colour (%)	Rock out crop (%)
1.	2570	30	30	20	7.5 Y R2.5/1	0
2.	2460	18	20	2	7.5 Y R3/2	15
3.	2520	52	23	15	2.5 Y R3/2	3
4.	2500	40	20	5	2.5 Y R3/2	2
5.	2620	50	48	1	10 Y R3/2	0
6.	2730	6	18.6	3	7.5 Y R3/3	7
7.	2630	60	19.4	3	7.5 Y R2.5/3	30
8.	2590	84	15.0	15	2.5 Y R2.5/1	10
9.	2620	64	21.0	3	10 Y R3/2	0
10.	2680	62	21.0	3	7.5 Y R2.5/2	4
11.	2620	70	21.6	2	7.5 Y R2.5/1	10
12.	2500	84	40.4	1	7.5 Y R3/2	8
13.	1820	35	15.0	2	7.5 Y R3/2	30
14.	1880	40	9.0	10	7.5 Y R3/2	0
15.	1870	19	13.5	0	7.5 Y R3/2	4
16.	2020	80	9.5	0	7.5 Y R3/1	0
17.	1900	49	15.2	0	7.5 Y R3/2	1
18.	1880	60	10.0	8	7.5 Y R3/2	0
19.	2150	54	11.0	4	7.5 Y R3/2	0
20.	2040	62	6.6	3	10 Y R2/2	0
21.	2120	55	17.6	2	7.5 Y R3/2	0
22.	2100	75	10.0	6	10 Y R3/2	6
23.	1900	40	13.0	6	5 Y R3/4	0
24.	1940	52	15.8	7	7.5 Y R3/2	2
25.	1300	32	14.8	45	10 Y R3/3	15
26.	1240	10	30.5	20	7.5 Y R4/4	0
27.	1280	22	21.2	20	10 Y R3/3	1
28.	1270	28	5.4	10	7.5 Y R3/4	40
29.	1320	80	9.6	5	7.5 Y R3/4	60
30.	1300	46	6.0	30	10 Y R3/4	45
31.	1240	6	7.2	20	10 Y R3/4	0
32.	1340	10	13.4	25	7.5 Y R4/4	30

Appendix3 Continued

33.	1360	22	13.6	25	10 Y R3/3	60
34.	1325	67	21.6	18	7.5 Y R5/4	20
35.	1400	40	21.0	10	7.5 Y R6/4	10
36.	1400	8	17.0	17	7.5 Y R5/2	40
37.	1300	32	17.8	60	7.5 Y R5/4	5
38.	1285	55	22.0	50	7.5 Y R3/4	20
39.	1370	16	17.2	60	7.5 Y R4/4	20
40.	1300	61	16.4	15	7.5 Y R5/4	40
41.	1310	71	15.4	15	7.5 Y R3/4	70
42.	1295	69	14.6	26	7.5 Y R4/4	60
43.	1950	49	26.2	2	7.5 Y R3/2	-
44.	1780	64	29.5	10	10 Y R2/2	2
45.	1880	37	31.4	3	7.5 Y R3/2	-
46.	1800	60	25.4	27	7.5 Y R3/2	5
47.	1830	79	21.0	5	7.5 Y R3/2	10
48.	1720	60	29.6	3	7.5 Y R3/2	5
49.	2620	65	25.6	0	10 Y R3/1	80
50.	2560	70	23.2	6	10 Y R3/2	4
51.	2600	80	30.0	1	10 Y R2/1	4
52.	2700	48	27.0	0	10 Y R3/2	-
53.	2710	53	29.8	0	10 Y R2/1	-
54.	2620	65	20.6	0	10 Y R3/2	45

Appendix 4 ***Results of Laborators Analysis of Soil Sata***

Coll No.	PH 1:2.5	EC mmhos	Sand(%)	Silt(%)	Clay(%)	Class
1.	6.99	0.05	38	42	20	L
2.	6.91	0.02	62	30	8	SL
3.	6.98	0.04	52	38	10	SL
4.	6.53	0.05	54	34	12	SL
5.	6.62	0.07	50	38	12	L
6.	6.23	0.05	54	32	14	SL
7.	6.55	0.03	54	30	16	SL
8.	6.57	0.07	52	36	12	SL
9.	7.08	0.16	40	40	20	L
10.	6.50	0.05	40	38	22	L
11.	7.08	0.20	46	40	14	L
12.	6.32	0.04	54	36	10	SL
13.	7.07	0.10	48	36	16	L
14.	7.19	0.08	48	32	20	L
15.	7.03	0.07	70	20	10	SL
16.	7.08	0.06	50	34	16	L
17.	6.93	0.10	56	28	16	SL
18.	7.38	0.21	54	32	14	SL
19.	7.05	0.05	70	22	8	SL
20.	7.12	0.06	54	30	16	SL
21.	6.18	0.07	53	34	13	SL
22.	7.41	0.15	55	34	11	SL
23.	6.91	0.06	51	36	13	L
24.	7.26	0.03	59	30	11	SL
25.	7.81	0.07	61	22	17	SL
26.	7.74	0.17	55	30	15	SL
27.	7.90	0.11	63	22	15	SL
28.	7.50	0.05	73	16	11	SL
29.	7.63	0.08	67	22	11	SL
30.	7.78	0.12	65	24	11	SL
31.	7.87	0.10	69	22	9	SL
32.	7.54	0.07	67	24	9	SL
33.	7.90	0.11	67	22	11	SL
34.	7.43	0.07	67	22	11	SL
35.	7.99	0.09	71	22	7	SL

Appendix 4 Continued

36.	7.60	0.08	65	24	11	SL
37.	7.37	0.06	73	18	9	SL
38.	7.79	0.08	63	22	15	SL
39.	7.86	0.15	67	24	9	SL
40.	7.84	0.09	63	28	9	SL
41.	7.65	0.05	69	22	9	SL
42.	7.92	0.10	59	32	9	SL
43.	7.16	0.02	54	20	20	SCL
44.	7.09	0.06	50	32	18	L
45.	6.99	0.03	44	36	20	L
46.	7.26	0.09	46	36	18	L
47.	8.03	0.06	62	24	14	SL
48.	8.12	0.06	68	22	10	SL
49.	6.79	0.06	50	40	10	L
50.	6.70	0.03	42	38	20	L
51.	6.62	0.03	42	44	14	L
52.	7.25	0.08	46	36	18	L
53.	6.81	0.05	40	40	20	L
54.	6.60	0.04	48	38	14	L

SL = Silt loam/sandy loam
L= Loamy, SCL silt-clay-loam

Appendix 4 Continued

Coll No.	*T.N(%)*	*O.C(%)*	*C/N*	*O.M(%)*	*AV.P. (ppm)*
Coll.No.	T.N(%)	O.C(%)	O.M(%)	Av.p(ppm)	
1.	0.245	2.394	10	4.127	2.72
2.	0.049	0.658	13	1.134	1.50
3.	0.091	1.476	16	2.545	1.60
4.	0.259	3.192	12	5.503	3.70
5.	0.357	4.708	13	8.117	3.50
6.	0.371	4.469	12	7.705	49.08
7.	0.245	3.252	13	5.607	3.12
8.	0.357	4.988	14	8.599	4.18
9.	0.441	5.945	13	10.249	10.02
10.	0.287	3.411	12	5.881	40.72
11.	0.280	3.192	11	5.503	6.48
12.	0.336	3.771	11	6.501	2.98
13.	0.273	3.651	13	6.294	6.40
14.	0.266	3.132	12	5.399	3.38
15.	0.273	3.252	12	5.606	5.26
16.	0.553	4.868	9	8.392	3.44
17.	0.273	3.491	13	6.019	5.86
18.	0.273	3.392	12	5.848	18.22
19.	0.119	1.397	12	2.408	2.28
20.	0.371	3.292	9	5.675	3.22
21.	0.329	3.731	11	6.432	4.50
22.	0.518	6.903	13	11.901	7.68
23.	0.294	3.372	11	5.813	4.40
24.	0.182	2.234	12	3.851	1.88
25.	0.105	1.017	10	1.753	1.12
26.	0.287	2.613	9	4.505	7.20
27.	0.119	1.137	10	1.960	2.44
28.	0.091	0.938	10	1.617	1.98
29.	0.266	2.594	10	4.472	3.36
30.	0.245	2.534	10	4.369	5.48
31.	0.147	1.516	10	2.614	2.22
32.	0.133	1.277	10	2.202	2.02
33.	0.119	1.456	12	2.510	1.68
34.	0.133	1.656	12	2.855	1.64
35.	0.119	1.017	9	1.753	1.12
36.	0.175	2.075	12	3.577	2.44
37.	0.161	1.975	12	3.405	1.76
38.	0.147	1.496	10	2.579	1.36

Appendix 4 Conatinued

Coll No.	*T.N(%)*	*O.C(%)*	*C/N*	*O.M(%)*	*AV.P. (ppm)*
39.	0.161	1.416	9	2.441	2.84
40.	0.147	1.736	12	2.993	3.24
41.	0.133	1.596	12	2.752	1.58
42.	0.161	1.676	10	2.889	3.90
43.	0.154	2.055	13	3.543	1.44
44.	0.182	2.334	13	4.024	2.16
45.	0.203	2.414	12	4.162	4.06
46.	0.21	2.534	12	4.369	3.58
47.	0.154	1.616	10	2.786	2.34
48.	0.14	1.476	11	2.545	2.20
49.	0.756	9.736	13	16.785	4.42
50.	0.224	2.693	12	4.643	11.64
51.	0.336	4.988	15	8.599	2.78
52.	0.392	5.107	13	8.805	74.62
53.	0.518	6.703	13	11.556	71.96
54.	0.504	6.623	13	11.418	11.20

Appendix 4 Continued

Exchangeable Cations

	Na	*K*	*Ca*	*Mg*	*Sum*	*CEC(Meg/100*	*Bas.Sa.(%)*
	Na	K	Ca	Mg	Sum	CEC(Meg/100)	Bas>(%)
1.	0.23	0.38	35.93	12.66	49.20	52.20	94
2.	0.23	0.43	37.43	18.16	56.25	54.60	103
3.	0.15	0.12	26.45	10.33	37.05	39.00	95
4.	0.23	0.30	32.93	10.50	43.96	54.40	81
5.	0.23	0.40	44.91	10.58	57.48	55.00	102
6.	0.62	2.37	43.91	10.58	57.48	60.08	96
7.	0.23	0.33	29.94	10.00	40.50	44.60	91
8.	0.31	0.48	42.42	10.41	53.62	53.20	101
9.	0.31	0.73	44.91	9.75	55.70	64.68	86
10.	0.38	1.13	38.42	10.16	50.09	58.00	86
11.	0.23	0.40	29.44	7.41	37.48	43.40	86
12.	0.31	0.40	26.45	11.00	38.16	48.20	79
13.	0.38	0.78	34.43	6.83	42.42	46.40	91
14.	0.31	0.68	29.94	8.91	39.84	47.40	84
15.	0.23	0.48	35.93	6.50	43.14	42.60	101
16.	0.31	0.53	38.92	10.08	49.84	53.60	93
17.	0.38	0.58	35.93	11.16	48.05	47.00	102
18.	0.38	0.85	35.43	6.50	43.16	49.20	88
19.	0.38	0.40	42.42	12.00	55.20	57.60	96
20.	0.31	0.40	34.93	8.00	43.64	43.00	101
21.	0.38	0.58	36.43	8.41	45.80	51.20	89
22.	0.46	0.85	45.41	8.41	55.13	55.60	99
23.	0.46	0.90	38.92	8.58	48.86	51.00	96
24.	0.31	0.32	27.94	6.83	35.40	40.00	89
25.	-	-	-	-	-	-	-
26.	-	-	-	-	-	-	-
27.	-	-	-	-	-	-	-
28.	0.31	0.46	33.43	3.17	37.37	30.40	123
29.	-	-	-	-	-	-	-
30.	-	-	-	-	-	-	-
31.	-	-	-	-	-	-	-
32.	0.39	0.38	36.43	4.50	41.70	33.40	125
33.	-	-	-	-	-	-	-

Appendix 4 *Continued*

	Na	*K*	*Ca*	*Mg*	*Sum*	*CEC(Meg/100*	*Bas.Sa.(%)*
34.	0.39	0.23	44.41	0.75	45.78	33.20	138
35.	0.47	0.36	29.94	4.25	35.02	33.60	104
36.	-	-	-	-	-	-	-
37.	-	-	-	-	-	-	-
38.	-	-	-	-	-	-	-
39.	0.47	0.36	1.58	29.94	32.35	27.60	117
40.	-	-	-	-	-	-	-
41.	-	-	-	-	-	-	-
42.	-	-	-	-	-	-	-
43.	-	-	-	-	-	-	-
44.	-	-	-	-	-	-	-
45.	-	-	-	-	-	-	-
46.	-	-	-	-	-	-	-
47.	-	-	-	-	-	-	-
48.	-	-	-	-	-	-	-
49.	-	-	-	-	-	-	-
50.	-	-	-	-	-	-	-
51.	-	-	-	-	-	-	-
52.	-	-	-	-	-	-	-
53.	-	-	-	-	-	-	-
54.	-	-	-	-	-	-	-

Appendix 5

Mean Values of Exchangeable Cations for three major clusters and nine sub-clusturs

Clusters	Exchangeable Cations Meq/100gm soil						
	Na	K	Ca	Mg	Sum	CEC Meq/100	Bas.Sa.(%)
A	0.29	0.64	35.97	10.31	47.21	52.07	90.6
B	0.39	0.59	36.47	9.26	46.67	46.67	94.8
C	0.41	0.39	29.16	8.52	38.45	31.64	121.4

Sub-Clusters	Na	K	Ca	Mg	Sum	CEC Meq/100	Bas.Sa.(%)
a	0.308	0.634	37.6	10.8	49.3	55.3	89.2
b	0.308	0.68	36.2	9.8	47.0	51.4	91.2

Exchangeale Cations							
Sub-Clusters	Na	K	Ca	Mg	Sum	CEC Meq/100	Bas.Sa.(%)
c	0.325	0.453	37.8	11.64	50.2	51.6	97.3
d	0.35	0.656	34.1	8.19	43.3	46.2	93.0
e	0.385	0.69	42.42	9.25	52.5	54.6	96.0
f	0.39	0.38	36.43	4.5	41.7	33.4	125
g	0.47	0.36	15.8	17.1	33.73.	30.6	110.5
h	0.39	023	44.41	0.75	45.78	33.2	138
I	0.31	046	33.43	3.17	37.37	30.4	423

CEC= Cation Exchange Capacity
Bas.Sa.= Base Saturation

DECLARATION

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

Name :- Mengistu Gonsamo

Signature ____________

Place and date of submission:
Addis Ababa University
May, 1998