AN ECOLOGICAL STUDY OF THE VEGETATION OF THE HARENNA FOREST

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CONTENTS

ABSTRACT

An ecological study of the vegetation of the Harenna forest was performed from April 1986 to October 1986. Data on the vegetation and environmental factos were collected, i.e. enumeration of tree and shrub species, an estimate of cover abundance value for herbs, epiphytes and lianes, altitude, edaphic factors and topography.

The program GROUPAGE was used to summarize the vegetation data. The program CHECK was employed to analyse species diversity. Five homogeneous clusters of vegetation were recognized using the presence-absence and quantitative data. The clusters obtained were compared for the mean values of the environmental factors using the statistic t-test.

The highest number of significant contrasts among the clusters were observed to result from variation in altitude. Analysis of species diversity showed that with increasing altitude, tree and shurb species decrease while herbaceous species, epiphytes and lianes increase in number. As a result, in the area of the Harenna forest, the main vegetation gradient is caused by differences in altitude associated with variation in moisture. The moisture gradient is accompanied by gradients in soil physical and chemical properties and topography.

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1. INTRODUCTION

1.1 Scope of the Problem

Extensive forests once covered much of Ethiopia. Indiscriminate clearing of the vegetation for cultivation, overgrazing and exploitation without replanting reduced the forest area and, now, left the country with limited forest resources. These forests were reduced in the last 3000 years from 40% (Hurni, 1986) to 16% in 1950's (Hedberg, 1979), 8% in 1960's (Wolde Michael, 1961), 4% in 1975's (Hedberg, 1979) to 3% at present (Hurni, 1986).

The high rate of deforestation and ruthless exploitation of most forests has caused serious ecological and socio-economic problems. Large areas of the country are now exposed to and experiencing heavy erosion. It is estimated that every year 900 million tons of soil are lost (Hurni, 1986). Under present conditions, the main sources of energy in rural areas is wood. Where wood is not available cow-dung, straws, shrubs, and herbaceous ground cover are used. In 1982, the Food and Agricultural Organization (F.A.O), reported that there are about 3.6 million rural households using fuel from crop residues and/or animal dung at the expense of their use for agricultural purposes.

With increasing human and livestock population pressure irreparable damage to the vegetation cover is imminent. Only relict patches of natural forests are found in Ethiopia at present. Yet forest vegetation clearance will apparently continue for some time to come for the simple reason that

forests are still the principal sources of fuel and construction material for the rural and part of the urban population.

Meaningful planning to rationally utilize the forest resources should be based on the ecological assessment of the existing natural forests. The Harenna forest, in southern Ethiopia, is one of the few remaining natural forests in the country. The main objectives of this study are:

(i) to characterize the vegetation of the Harenna forest,

(ii) to relate the vegetation cover with some environmental parameters, and

(iii) to provide information that would suggest solutions to some conservation problems of that particular forest.

To meet with these objectives, a classification procedure is employed to study the ecology of the Harenna forest.

1.2 Background to the Study Area

1.2.1 General features

The Bale mountains massif forms part of the eastern highland of Ethiopia. The Harenna forest on the southern slopes of the Bale mountains lies approximately between longitudes 39°E and 40°E and latitudes 6°N and 7°N (Fig. 1 attached to the inside back cover). According to Hillman (1986), the Harenna forest constitutes the largest subsection of the Bale Mountains National Park. The Harenna escarpment, the main and very conspicuous topographical unit, falls in altitude to the south first in almost vertical

steps from 3800m to 2800m, then it stretches with moderate slopes in altitude to 2300m. The slope from there to the lowermost limit of the forest is much gentler. The Harenna forest constitutes the entire catchment area of the rivers and many streams which are tributaries of the Welmel river that drains into the Genale river.

1.2.2 Geology

The Bale mountains appear to be (Mohr, 1963) of volcanic origin resulting from the Oligocene erruptions of the Trappean lava which cover the mesozoic strata. The rock in Bale mountains is trachytes, with some rhyolites, basalts, agglomerates and tuffs (Horton, 1976).

The Bale mountains show distinct signs of recent glaciation (Smeds, 1959; Hedberg, 1978). This phenomenon and other forms of erosion following tectonic uplifts of the Bale mountains have modified the original topography to the present landscape.

According to Weinert and Mazurek (1984), the basalts and trachytes in the Bale mountains weather to mainly red or redbrown to black silty loam. It appears, therefore, that the substrate of the Harenna forest is the outcome of the decomposition of volcanic materials.

1.2.3 Climate

A generalized account of the climate on the south-eastern parts of Ethiopia is given by Kebede (1964), Suzuki (1967), and Daniel (1977, 1986). Hillman (1986) provides a more detailed account of the climate of the

Bale mountains. This author summarizes the climate of that particular area (Table 1a to 1c) as a four-months dry season (November - February) with low rainfall, low humidity, low nocturnal and diurnal temperatures; an eight-months wet season (March - October) with high rainfall, high humidity, and higher nocturnal, lower diurnal temperatures than in the dry season.

There are no climatic data for the area of the Bale mountains covered by the Harenna forest, but the climatic conditions described by Hillman (1986), somewhat hold true for this area too. Local variation in climate could, however, exist over the area largely as a result of variation in altitude and orientation of the mountain massif which is formed of an east-west escarpment (the Harenna-escarpment). This position of the escarpment is certainly of importance with regard to the prevailing winds that bring rain to the area. The Harenna escarpment appears to intercept the flow of moist air currents from the south, thus increasing the precipitation in the area, and causing dense mists to form (Hillman, 1986), between 2300-3000 m for most of the day during the rainy season which lasts for about eight months.

1.2.4 Vegetation

The existence of a large block of comparatively humid forest on the southern slopes of the Bale mountains was probably initially made known through the works of Mooney (1963). Later on, a number of studies made by Chaffey (1979), Friis (1986), Hillman (1986), Mesfin (1986), and

Table 1a. Mean monthly rainfall for locations in and near Bale Mountains National Park (BMNP)

Location	Mena	Chorchora	Koromi	Konteh	Goba	Dinsho
Source of information	4	3	3	3	1	2
Altitude (m ASL)	1330	3500	3850	4050	2750	3170
Jan.	0.0	13.3	14.1	7.4	21.1	13.0
Feb.	18.2	26.8	23.5	33.9	33.0	23.0
March	40.5	86.8	103.9	118.3	56.5	89.9
April	149.4	210.4	204.4	140.1	133.4	146.4
May	137.7	112.1	132.6	82.7	130.5	113.1
June	24.7	71.0	80.7	56.1	53.2	75.1
July	0.9	82.6	104.6	84.6	89.3	164.9
August	0.7	139.6	144.1	105.2	107.5	183.6
Sept.	3.7	184.9	165.4	127.9	131.4	162.3
Oct.	2.4	52.7	77.1	50.1	84.6	132.4
Nov.	8.8	28.5	33.1	23.7	31.2	30.9
Dec.	0.1	11.9	11.5	9.6	13.9	15.2
Total	387.1	1020.5	1094.8	839.5	885.1	1150.1

1. Ethiopian National Meteorological Services Agency (ENMSA) - 1973-1985).
2. Dinsho Park records (1969-1985)
3. Bale Mountains Research Project (June 1984 - Dec. 1986).
4. Min. of Agriculture Office. (Jan. 1983 - Dec. 1984).

Table 1b. Mean monthly maximum and minimum temperatures (°C) for locations in and near BMNP).

	Maximum temperatures			Minimum temperatures	
Location	Goba	Dinsho	Location	Goba	Dinsho
Source of information	1	2	Source of information	1	2
Altitude (m ASL)	2750	3170	Altitude (m ASL)	2750	3170
Jan.	21.0	17.6	Jan.	4.3	0.6
Feb.	21.7	18.9	Feb.	5.1	1.2
March	20.2	19.8	March	6.0	2.5
April	20.4	18.7	April	8.1	5.3
May	20.5	17.4	May	8.3	5.2
June	21.1	17.0	June	7.5	4.9
July	20.4	16.5	July	7.6	4.6
August	20.0	16.8	August	7.6	5.3
Sept.	19.4	16.7	Sept.	7.6	4.9
Oct.	18.1	14.7	Oct.	7.28	4.6
Nov.	19.0	15.9	Nov.	5.2	2.5
Dec.	20.2	16.7	Dec.	3.9	2.1
Annual mean	20.2	17.2	Annual mean	6.5	3.7
WS mean	20.0	17.2	WS mean	7.5	4.7
DS mean	20.4	17.3	DS mean	4.6	1.6

1. ENMSA - (1973-1985).
2. BMNP data - (Oct. 1983 - July 1985)

WS - Wet season (March - October).

DS - Dry season (November - February).

Table 1c. Mean Monthly Relative Humidity (%) at Goba and Dinsho.

Month	Goba (1)	Dinsho (2)
Jan.	60.2	45.1
Feb.	60.0	39.5
March	63.3	50.1
April	74.0	71.1
May	72.0	86.2
June	72.7	91.6
July	74.6	86.3
August	77.0	85.5
Sept.	77.0	96.4
Oct.	77	70.3
Nov.	69.3	62.9
Dec.	61.8	59.1
Annual mean	70	70.3
WS mean	73.5	79.7
DS mean	62.8	51.7

(1) ENMSA - (1973 - 1985)

(2) BMNP data - (Oct. 1983 - July 1985)

WS - West season (March - October)

DS - Dry season (November - February).

Uhling (1986) have shown the vegetation of the Harenna forest to be both structurally and compositionally diverse. These studies on the Harenna forest have contained general descriptions of the vegetation types and have been mainly floristic in nature. The following description of the vegetation draws information from the above cited works and adds details from the writer's own observations.

The lower-most portion of the Harenna forest, between 1500 - 1670 m, is represented by a relatively dry forest type. The upper storey of this forest is dominated by Podocarpus gracilior Pilg. The intermediate storey consists of Filicium decipiens (Wight & Arn.) Thw., Warburgia ugandensis Sprague, Ocotea kenyensis (Chiov.) Robyns & Wilczek, Croton macrostachys Del. Celtis africana Burm f., Olea hochstetteri Baker, Olea welwitchii (Knobl.) Gilg. & Schellenb., Polyscias fulva (Harms.) Harms., Syzygium guineense (Willd.) DC., and Strychnos mitis S. Moore. The lowermost stratum is composed of Teclea nobilis Del., Teclea simplicifolia (Engl.) Verdoon, Vepris dainellii (Pichi-Serm.) Kokwaro, Rhamnus prinoides L'Herit, Coffea arabica L., and Allophyllus macrobotrys Gilg., and in places these form quite a dense cover. The forest floor is not rich in species composition; it is mainly covered by Asystasia gangetica (L.) T. Anders Acanthopale sp., Oplismenus compositus (L.) P. Beauv., Hypoestes aristata Vahl, and Panicum monticolum Hook. f. Only few lianes as Landolphia buchananii (Hall.

f.) Stapf, Pterolobium stellatum (Forssk.) Brenan, Hippocratea africana (Willd.) Loes, Gouania longispicata Engl., and Caesalpinia volkensii Harms occur in this forest zone. Epiphytes are not common in this part of the Harenna forest.

At elevations between 1670 - 1850 m. the natural vegetation consists of a mixture of the Podocarpus and Aningeria forests, growing intermediary between the lower and drier quarter of the former and the higher, warmer-humid habitat of the latter. The upper storey is mainly dominated by Podocarpus gracilior and Aningeria adolfi-friedericii (Engl.) Robyns & Gilbert. In the intermediate storey are found Ocotea Kenyensis, Warburgia ugandensis, Olea hochstetteri, Polyscias fulva, Strychnos mitis, Celtis africana, Allophyllus abyssinicus (Hochst.) Radlk., and Syzygium guineense. The lowermost stratum is composed of Coffea arabica, Ehretia cymosa Thonn., Erythrococca sp., Galiniera coffeoides Del., Teclea nobilis, Vepris dainellii, Turrae holstii Gürke, Dracaena steudneri Engl., and Maytenus arbutifolia (Hochst. ex. A. Rich) Wilczek. The ground cover is richer in species composition than the previous zone; common species include Asystasia gangetica, Oplismenus compositus, Acanthus sennii Chiov, Isoglossa somalensis Lindau, Isoglossa punctata (Vahl.) Brummitt ex. Wood, Hypoestes aristata Acanthopale sp., and Panicum monticolum. Lianes such as Gouania longispicata, Jasminum grandiflorum L. subsp. floribundum (R. Br. ex. Fresen) P.S. Green, Landolphia buchananii, Jasminum abyssinicum DC. and Pterolobium stellatum occur

in this zone of the Harenna forest. Ground ferns (e.g. Asplenium lividum Mett. ex. Kuhn), Epiphytic ferns (e.g. Asplenium protensum Schrad.) mosses and Orchids (e.g. Aerangis luteo-alba (Kranzl.) Schltr. var rhodosticata (Kranzl.) J. Stewart) are also found in this forest zone.

At higher elevations, i.e., between 1850 - 2160 m is the zone including wetter and more humid forest of the region. The upper storey is dominated by Aningeria adolfi-friedericii. The intermediate storey is formed of a variety of tall trees such as Syzygium guineense, Allophyllus abyssinicus, Croton macrostachys, Erythrina brucei Schweinf, Prunus africana (Hook. F.) Kalk, Ficus sur Forssk, Polyscias fluva and Olea hochstetteri. A lower storey of small trees and shrubs consists of plant species such as Teclea nobillis, Galiniera coffeoides, Vepris dainellii, Lepidotrichilia volkensii (Gürke) Leroy, Bersema abyssinica Fresen, Cassipourea malosana (Bak.) Alston, Maytenus undatus (Thunb.) Blakelock, Dracaena afromontana Mildbr., Dracaena steudneri, and Brucea antidysentrica J.M. Mill. These strata of vegetation are usually joined by climbers including Urera hypselodendron (A.Rich.) Weddel., Jasminum abyssinicum and, Basella alba L. The ground cover is rich in species composition and consists Acanthus sennii, Cerastium octandrum A. Rich, Droguetia iners (Forssk.) Schweinf, Elatostema monticolum Hook.f, Giradiania diversifolia (Link.) Friis, Giradinia bullosa (Steud.) Weddel, Asystasia gangetica, Oplismenus compositus, Isoglossa somalensis Lindau, and Pilea johnstonii Oliv. Epiphytic ferns

(e.g. Drynaria volkensii Hiern), mosses, Orchids (e.g. Bulbophyllum josephii (O. Ktze.) Summerh.) and lichens are very well represented in this vegetation zone.

At altitudes between 2160 - 2800 m, the vegetation is characterized by Schefflera - Hagenia forest. The upper canopy is dominated by Schefflera abyssinica (A. Rich.) Harms. and Hagenia abyssinica (Bruce.) J.F. Gmel, the latter becoming dominant between 2400 - 2800 m. Associated with these are Prunus africana, Dombeya torrida (J.F.Gmel.) Bamps, and Croton macrostachys. The lower storey consists of smaller trees and shrubs such as Bersema abyssinica, Brucea antidysentrica, Cassipourea malosana, Ilex mitis (L.) Radlk, Nuxia congesta Fresen, Canthium oligocarpum Hiern, Rubus apetalus Poir., Rapanea simensis (Dc.) Mez., Hypericum revolutum Vahl., and Erica arborea L., the latter three species are increasingly abundant in the upper limit of this vegetation zone. The tall trees harbour many epiphytes including Canarina eminii Schweinf, Lycopodium dacrydiodes Baker, various ferns (e.g. Elaphoglossum lastii (Baker) C.Chr.), mosses and Orchids (e.g. Diaphananthe schimperiana (A. Rich.) Summerh.) Besides,climbers such as Urera hypselodendron, Embelia schimperi Vatke, Schefflera myriantha (Bak.) Drake, and Basella alba occur in this zone. This vegetation zone, between 2400 - 2600 m, is interspersed with patches of Arundinaria alpina K. Schum. The ground cover of this forest is very rich in herbaceous plants compared to the previous zones, owing to high availability of moisture in the area.

Commonly found species include Impatiens aethiopica Grey-Wilson, Impatiens rothii Hook.F., Lobelia scebelii Chiov., Sanicula elata Buch. -Ham. ex.D. Don., Anthoxanthum aethiopicum I.Hedb., Pilea johnstonii Oliv, Galium aparinoides Forssk, Stachys aculeolata Hook.f. various ferns (e.g. Polystichum setiferum (Forssk) Moore ex. Woynar var. fuscopaleaceum (Alston) Schelpe) mosses and lichens.

Above this vegetation zone, i.e., between 2800 and 3250 m - the tree line, the most characteristic species are Hypericum revolutum, Erica arborea, Schefflera volkensii (Harms) Harms, and Hagenia abyssinica. The shrub layer is mainly composed of Discopodium penninervum Hochst. The ground cover is rich in herbaceous plants, ferns and mosses. At higher altitudes of this zone the Hagenia abyssinica and Hypericum revolutum branch-ends are often hidden under Usnea. This upper altitudinal limit of the Harenna forest gives way to sub-alpine vegetation type, characterized as Erica bushland.

1.2.5 Population and Landuse

The Harenna forest is sparsely populated; permanent settlement being limited to a few scattered villages. The majority of the people are pastoralists. Besides, beekeeping is a very important source of their economy. Many bee-hives could be observed in the forest on such favored trees as Polyscias fulva, Schefflera abyssinica and Celtis africana.

Because of the recent road construction into the forest some land clearing for cultivation, and heath burning for grazing has already taken place, especially at higher altitudes. This indicates a tendency to shift from purely pastoral economy to a settled agricultural economy with the attendant increment in population density since the time of Mooney (1963).

At lower altitudes in the forest, lumbering and tree felling have been common practices of the inhabitants of Dollo-Mena, a town c. 9.5km from the lower altitudinal limit of the Harenna forest. In addition, the Mena Sawmill, though stated by Hillman (1986) to have stopped its functions still uses the forest as source of wood for timber production. The trees that are used for this purpose are Podocarpus gracilior, Warburgia ugandensis, Prunus africana and Olea hochstetteri.

2. LITERATURE REVIEW

2.1 The Vegetation of Ethiopia

A number of authors have attempted to describe the vegetation of Ethiopia taking several factors into consideration, climate and altitude being the most important. Among these are Russ (1945), Breitenbach (1961, 1963), Beals (1968), Mesfin (1972), Daniel (1977), Friis et al. (1982), White (1983), Zerihun (1985), and Tewolde (1986). Although most classifications are aimed at distinguishing ecologically homogeneous zones, they differ in one way or another according to the set objectives. Nevertheless, the efforts made by these authors towards the understanding of the vegetation of the country are of paramount significance.

The approach towards the classification of the Ethiopian vegetation has been, largely, by way of identifying the major physiognomic types. The most intensive physiognomic study is perhaps that of Pichi-Sermollis' (1957). He recognized 24 vegetation units in order to establish a geobotanical map of Ethiopia and Somalia. A similar and carefully prepared scheme of classification was provided by Breitenbach (1961, 1963). He stated that the principal physiognomic types of natural vegetation are well in accordance with altitude or temperature zones, so that lowlands are characterized by steppes, savannas and woodlands, while the highlands merging into the higher

mountains are occupied by forests which "dissolve" again into woodlands, savanna and steppes. Similarly, Daniel (1977) by showing the close relationship between climate and altitude on the one hand and vegetation on the other classifies the Ethiopian vegetation in much the same way as Breitenbach's (1961, 1963). In Ethiopia grasses do not form a true savanna (Tewolde, 1986) and Greenway (1973), Friis et al. (1982), White (1983) and Zerihun (1985) state that the use of such terms as savanna and steppe may have different ecological use and implications.

On the other hand, Beals (1968), Friis et al. (1982) and Tewolde (1986), by generalizing the smaller units into such broad zones, have similar approach towards establishing a scheme of classification of the Ethiopian vegetation. They differ, however, in the assignment of altitudinal limits to their vegetation zones. Otherwise, the description given to the different vegetation types seem to agree.

Though, the vegetation zonation is much less distinct, because of human interference, the sparse remains of natural vegetation fit into zonation system designed for the area (Hedberg, 1978). As a result, following the suggestions of Beals (1978), Friis et al. (1982) and Tewolde (1986), the natural vegetation can, in broad terms, be classified into the zones listed below:

1. Afroalpine and subafroalpine
2. Dry evergreen montane forests and associated grasslands
3. Moist evergreen montane forests

4. Evergreen montane woodlands and scrubs
5. Deciduous woodlands
6. Lowland semi-desert and desert vegetation
7. Coastal vegetation

The following notes regarding the physiognomic types are based on the descriptive accounts given by Pichi-Sermolli (1957), Breitenbach (1963), Beals (1968), Greenway (1973), Hedberg (1978), Galperin (1978), Friis et al. (1982), White (1983), Zerihun (1985) and Tewolde (1986).

The afroalpine zone covers areas which are, on average, higher than 3,200 meters on the north-western and south-eastern plateaux. In this zone, higher up in altitudes, the vegetation consists of plant communities which are adapted to grow under the influence of low soil temperature, intense radiation during the day and cold temperature at night. Some of the plant species noticeable in this part of the afroalpine zone include Kniphofia spp., Helichrysum spp., Alchemilla spp., and Lobelia rhyncopetalum (Hochst.) Hemsl. The most striking plant species are undoubtedly Helichrysum citrispinum Del. which forms large cushion two meters or more in diameter and L. rhyncopetalum which grows to a height of 3 meters in this inhospitable climate.

Lower down in altitude, in the subafroalpine zone, the most extensive vegetation is Erica arborea/Philippia trimera Engl. scrub, with the latter restricted to the south-eastern plateau of the country. Originally this scrub was a woodland, but owing to repeated cutting and burning for the purpose of grazing and barely farming both

E. arborea and P. trimera, growing on thin soils, seldom attain more than three meters in height.

Meadow grasses comprising Agrostis quinqueseta (Hochst. ex. Steude.) Hochst. and Festuca schimperiana A. Rich. occur in this zone.

The evergreen montane forests covered originally an extensive part of the Ethiopian plateau. Pressure on land caused by an increase in human and livestock population has produced serious ecological problems.

The dry evergreen forests occur scattered in the northern, eastern and southern parts of the plateau. The Juniperus forest is mainly found in the upper, cooler and semi-humid regions of this zone. The Podocarpus forest is well represented in the lower and more humid region of the dry evergreen montane forest zone. These forests are more frequent and occur in large blocks in the south-eastern than in the north-western plateau. The most important species in this zone include Juniperus procera Hochst. ex. Endl., Olea africana, Podocarpus gracilior, and prunus africana. Associated with these are montane grasslands comprising of species of Hyparrhenia, Andropogon, Chloris and Pennisetum.

The moist evergreen montane forest occupies in large blocks the most humid region of the south - west and southern part of the country. The most spectacular forest in this zone is the Aningeria forest, consisting of Aningeria adolfi-friedericii and other co-dominants including Olea

hochstetteri, Prunus africana, Albizia schimperiana Oliv and Syzigium guineense. Regarding the general constitution of the Ethiopian montane evergreen forest, the Aningeria forest represents its most vigorous and impressive aspect.

In the upper altitudinal limits of this montane evergreen forests occur the evergreen woodland and scrub, comprising simpler forests of Hagenia abyssinica and/or Schefflera abyssinica with associated small trees of Hypericum revolutum, Rapanea simensis, and the shrub Discopodium penninervium, on deeper soils and Erica arborea scrub on thinner soils of the slopes. In the wettest sites stretches of bamboo forests, Arundinaria alpina, also occur. It should, however, be realized that the present anomalous distribution of Arundinaria alpina, at least in the south, can only be due to destruction of major and previously widespread bamboo thickets;by man caused fire and repeated cutting. Mooney (1963) stated of the heather and bamboo thicket in the Harenna escarpment, that owing to repeated cutting and burning major destruction has resulted to the vegetation of Erica arborea scrub and Arundinaria alpina thickets.

The variety of deciduous woodlands could be grouped as broad leaved and small leaved vegetation types. The broad leaved deciduous woodlands occur on deeper soils, moister western lower altitudes. This woodland is commonly dominated by Combretum spp., and Terminalia spp,. This

broad leaved deciduous woodland also contains stretches of bamboo, Oxytenanthra abyssinica (Rich.) Munro, which covers large areas in western Ethiopia. Along the rift valley and on drier, deep soil and sometimes on rockier soils of the eastern escarpment are found the small leaved deciduous woodlands. The common woodland species in this area are Acacia spp., Entada spp., Lannea spp., in deeper soils and Euclea schimperi (Dc.) Dandy, Dodonea viscosa (L.) Jacq., and Dobera glabra (Forssk.) Juss. ex. in Poiret in shallow soils. The grasses in deciduous woodlands are many, the commonest being Hyparrhenia spp. and Themeda triandra Forskal.

True desert, practically with no vegetation occurs only in the north east. An extensive part of the arid region is semidesert. The shrub layer of this vegetation type is dominated by Acacia and Commiphora. They cover an extensive area in south east. The most wide spread grass in the semi-desert region is Chrysopogon spp.. In the north east, where there is a true desert with essentially no vegetation, Chenopodium spp. are the common ephemerals.

The coastal vegetation type occurs along the Red Sea coast. Scattered mangrove forests are the chief features of the coastal vegetation.

2.2 Considerations in Vegetation Sampling

A detailed vegetation study is based on the description and investigation of plant communities that must first be recognized in the field. Community samples are the

the essential working material for community studies. Greig-Smith (1964, 1983), Shimwell (1971), Kershaw (1973), Mueller-Dombois and Ellenberg (1974), Goldsmith and Harrison (1976) and Gauch (1982) provide a comprehensive and detailed account of the importance of sampling a plant community so as to obtain the maximum information from one set of samples. However, it is necessary to outline the more important aspects of sampling since conclusions will be based on sampling procedure followed.

There are a wide range of kinds of samples that can be applied to plant community studies. According to Greig-Smith (1983), the object of sampling procedures, with few exceptions, fall into one or another of the following three categories: (a) an estimate of the overall composition of the vegetation with certain boundaries, with a view to comparison with other areas or with the same area at another time, (b) the investigation of variation within the area, or (c) correlation of vegetation differences with differences in one or more habitat factors.

The choice of sampling procedure involves many considerations.

The first important proviso in the choice of a sample stand is its homogeneity (Shimwell, 1971;Kershaw, 1973). The sample should be homogeneous in structure and composition if the purpose is to represent community types by samples or to relate vegetation to environment. Samples should also be taken of uniform environment (Whittaker 1973;Gauch 1982).

Assuming there is a reasonable degree of uniformity, the second consideration is that the sample should be large enough in area to represent effectively the composition of the plant community (Greig-Smith, 1964, 1983;Shimwell, 1971;Kershaw, 1973;Goldsmith and Harrison, 1976). It is obvious that as the sample size is increased a better measure of the mean of the population is obtained, but if the sample is too large difficulties are encountered in meeting the homogeniety of the sample stand and efficiency of sampling. As a result, the characteristics of a plant community appear when a certain minimum area is examined. Three relatively objective methods for selecting the minimal area of a community have been described, one based on species composition, a second on species frequency and the third on homogeneity of composition (Shimwell, 1971). Of the methods, the first which produces species-area relation curve is simple to use and effective (Goldsmith and Harrison, 1976). This minimum size requirement is related to the number of species which occur as sample stand increases in size (Kershaw 1973). Accordingly, Mueller-Dombois and Ellenberg (1974) suggest various sample sizes, for temperate zone vegetation, from 0.1 - 1 m^2 for lichen communities to 200 - 500 m^2 for forests (including tree stratum). Similarly, Tewolde (1975), Sebsebe (1981), Hailu (1982) and Sahle (1984) have employed a sample size of 400 m^2 to study woody vegetation in Ethiopia.

It should, however, be clear from the existence of pattern at numerous scales in apparently homogeneous vegetation that minimal area can never be more than a gross approximation and, accordingly, some subjective judgement is necessary in assessing whether the area sampled is large enough to reflect the characteristics of the particular community (Greig-Smith 1964, 1983;Kershaw, 1973).

Since considerable numbers of samples may be needed, the sampling procedure should be designed to obtain and record rapidly the kinds of information regarded as most important (Greig-Smith, 1964;Whittaker, 1973). Among the kinds of information that might be gathered about a plant community, some are more significant, appropriate to the character of the community and informative in relation to time spent and the purpose of the particular technique used to analyse the vegetation data than others. It appears, therefore, that sampling procedure must always be related to the importance of information sought to the problem under investigation and to the degree of precision necessary (Greig-Smith, 1964, 1983).

Sample stands may be located within an area selected on the basis of these considerations at random, systematically, by investigator's subjective choice of typical sites or combination of the former two (stratified sampling)(Whittaker, 1967, 1973, 1978;Shimwell, 1971;Kershaw, 1973;Gauch 1982).

Systematic sampling is the most widely used method of sampling a plant community. According to Gauch (1982), compared to random sampling errors introduced by the investigator's baised preconception and invalidity to statistical tests puts the method to a disadvantage. The method, however, has been preferred on the grounds that it is more representative of variations over the area and hence likely to give a better estimate than random samples, and that it is easier to carry out efficiently in the field (Greig-Smith, 1983).

2.3 Techniques of Analysing Vegetation Data

2.3.1 General

The descriptive and functional characteristics of vegetation result from the interactions between the properties of the plant species it contains and the environment in which they occur. A wide variety of multivariate techniques are now available to study the complex nature of plant communities. Multivariate analyses of plant communities primarily involve classification and ordination with the general purposes of summarizing large complex data sets obtained from community samples, aiding the interpretation of environmental factors, and hypothesis generation about community variation and structure (Gauch, 1982; Greig-Smith, 1983).

These two principal approaches towards vegetation study are allegedly based on different concepts of the essential nature of vegetation (Anderson 1965). Classification methods emanated from the belief that vegetation is composed of certain distinct and fairly discrete plant communities; i.e. the concept of community unit theory (Whittaker, 1967, 1970; Kumar, 1981; Goodall, 1978). Ordination is believed to have projected from the concept of vegetation as a continuum, which is connected with the principle of species individuality as augumented by Ramensky (1924) and Gleason (1926) (cited in Whittaker, 1962; McIntosh, 1967; Kershaw, 1973; Muller-Dombois and Ellenberg, 1974; Greig-Smith, 1980). These concepts of vegetation studies have had strong bearing on the methods applied in field research (Mueller-Dombois and Ellenberg, 1974). There has been considerable controvery between those ecologists who prefer classificatory procedures as being more satisfactory and meaningful and those who regard ordinational techniques for the same reasons, in the analyses of vegetation data (Anderson, 1965). It is now, however, generally recognized that both classification and ordination techniques could be appropriately applied to the same vegetation data, and that the choice between the two approaches depends on the ecological question to be answered rather than on the preconception about the nature of vegetation (Anderson, 1965; Gittins, 1965; Kershaw, 1968; Whittaker, 1970; Goodall, 1978; Greig-Smith, 1983). This study concerns only classificatory techniques to analyse the vegetation data.

2.3.2 Classification

Classification involves the arrangement of plant communities into classes; the members of each class have, in common, a group of attributes which serve to distinguish them apart from the members of other classes (Greig-Smith, 1980). The various techniques of community classification have well been discussed by Pielou (1969), Mueller-Dombois and Ellenberg (1974), Goldsmith and Harrison (1976), Gauch (1982) and Greig-Smith (1983). A detailed account of the development of classification techniques have been presented by Whittaker (1962) and Shimwell (1971).

All classification techniques have in common the aim of producing final groups which are as homogeneous in composition as possible (Greig-Smith, 1980). They, are, necessarily, approximations to reality but they do provide a simplifying procedure for the description of complex vegetational pattern. For this reason a classificatory approach has often proved useful during the preliminary investigations of large heterogeneous areas and before more lines of inquiry are required (Williams and Lambert, 1959; Goldsmith and Harrison, 1976). Accordingly, to Gauch (1982), the classification techniques used in plant community studies could be considered in three groups; table arrangement, non-hierarchical classification and hierarchical classification.

Detailed accounts of table arrangement are presented by Mueller-Dombois and Ellenberg (1974) and Westhoff and

Maarel (1978). Table arrangement is the earliest classification technique in community ecology. The advantage is that it exhibits at once both the general features and full details of the data set (Gauch, 1982). The Braun-Blanquet table work pursues to order the sample-by-species data matrix into the order that could reveal the inherent structure of the data (Mueller-Dombois and Ellenberg, 1974). As a result, the aim in table work is to arrange the species that brings together species similar in their distribution in the samples and likewise, to arrange the samples in the sequence that brings samples similar in composition. The non-zero data matrix entities are thereby concentrated into blocks, and lines may be drawn in the matrix of sample and species clusters (Gauch, 1982).

Three principal ideas are the essence of Braun-Blanquet approach (Westhoff and Maarel, 1978); (i) classification and interpretation of communities should be based on their full floristic composition, (ii) with emphasis on diagnostic species, whose relative restriction to samples characterizes communities and indicates their environments and (iii) which may be used to organize the communities into a formal, hierarchical classification. These authors judge the Braun-Blanquet method to be the most fully developed and most widely useful approach to classification and interpretation of vegetation. However, the Braun-Blanquet methodology exhibits certain limitations; the results are relatively subjective (Kershaw, 1973; Gauch, 1982), and the application

to unfamiliar species and unknown vegetation is difficult (Westhoff and Maarel, 1978). Nevertheless, the recent use of computer programs (e.g. TABORD) have reduced some of the limitations of Braun-Blanquet method, by increasing objectivity, reducing tedious labour and reducing the requirement of expertise (Gauch, 1982).

Non-hierarchical classification simply appropriates each sample or species to a cluster, placing similar samples or species together. The clusters are defined separately and the links between them have the form of a net-work rather than a dendrogram (Pielou 1969). Williams (1971) indicated that with a non-hierarchical classification it is the structure of the individual groups which is optimized, since these are made as homogeneous as possible. The non-hierarchical techniques aim to produce the most efficient groupings regardless of the route by which they are divided (Greig-Smith, 1983). For those applications in which homogeneity of groups is of prime importance, the non-hierarchical techniques are attractive (Williams, 1971). According to Gauch (1982), non-hierarchical classification is best appreciated by its potential of moderating noise, identifying outliers and summarizing redundancy. Non-hierarchical technique does not elucidate relationships, but it can produce far fewer composite samples which then make other multivariate analyses feasible and effective for analysing relationships. Because of the potential for raw data sets to be large, Gauch (1980), has demonstrated the use of non-hierarchical classification

for large rapid initial clustering of large data set, and has developed a computer programme, COMPCLUS, for this rapid initial clustering.

Hierarchical classification techniques arrange similar entities into classes and the classes at any level are subclasses of classes at higher level (Pielou, 1969; Everitt, 1980). The techniques always optimize a route between the entire popullation and the set of individuals of which they are composed. According to Williams et al. (1966) and Greig-Smith (1983), hierarchical procedures are better known, less clumbersome and ecologically more readily interpretable. Essentially, hierarchical techniques may be subdivided into an agglomerative method which progresses by successive fusions (Williams, 1971; Goodall, 1978), beginning with individuals that may be grouped until all individuals are finally fused into a single group, building a hierarchy from the bottom (Greig-Smith, 1980); and a divisive method which proceeds by progressive divisions, beginning with the whole set of data and decomposing it into individuals or at least into subgroups on the basis of an appropriate criterion to produce a hierarchy (Pielou, 1969; Williams, 1971; Greigh-Smith, 1980). Both types of hierarchical procedures may be viewed as attempts to find the most efficient steps, in some defined sense, at each stage in the progressive subdivision or synthesis of the data. Agglomerative techniques are probably more flexible both in the data which they will accept and the indices

which they employ (Goldsmith and Harrison; 1976; Goodall, 1978). However, unlike divisive procedures, agglomerative techniques face the following difficulty;the combining process is begun with the smallest units and these are the ones in which chance anomalies are most likely to obscure the true affinities. The result is that bad combinations may be made at an earlier stage in the fusion process and they will affect all subsequent combinations (Pielou, 1969). Further, the execution may be more time-consuming (Williams, 1971; Goldsmith and Harrison, 1976; Gauch, 1982, Greig-Smith, 1983). According to Williams (1971), the reason why agglomerative techniques are not completely replaced by divisive procedures lies in a monothetic and polythetic distinction.

In a monothetic procedure, division is based on a single attribute, that is, partition into subgroups is made on the presence or absence of a single character - usually species in the case of community samples (Gauch and Whittaker, 1981). In a polythetic procedure, on the other hand, partition is based on a measure of similarity or disimilarity applied over-all attributes, so that an individual is grouped with those individuals which, on the average it most resembles (Williams, 1971). Since with a monothetic procedure, the division attribute is selected not indiscriminately, but must depend on the properties of the population under study a monothetic agglomerative technique is impossible, except in a trivial sense (Williams and Dale, 1965; Williams et al, 1966; Williams, 1971).

A drawback of the hierarchical approach (Lambert and Williams, 1966) is that the decisions made are irrevocale. If the rules of the clustering algorithm, at a particular point in the process, lead to a certain division or a certain fusing of groups, this can never be corrected by subsequent actions within the strictly hierarchic procedure. This is worse for monothetic than for polythetic techniques (Everitt, 1980) and led some ecologists to amend it by allowing for the possibility of fusion among clusters that have been separated and have become associated with different branches of the dendrogram (Goodall, 1953; Greig-Smith et al, 1967; Crawford and Wishart, 1968).

The variety of hierarchical classification techniques may be summed up in three groups as follows: monothetic divisive, polythetic divisive, and polythetic agglomerative (Williams et al, 1966; Williams, 1971; Goldsmith and Harrison, 1976; Everitt, 1980; Greig-Smith, 1980, 1983; Gauch, 1982).

Monothetic divisive classification techniques begin with all the samples in a single group and then divide them hierarchically into progressively smaller groups on the basis of the presence and absence of a single species. Williams and Lambert (1959, 1960), presented a monothetic divisive procedure, association analysis, which has long been one of the most frequently used numerical classification methods in plant community studies, and is based on similar, earlier work of Goodall (1953). Monothetic divisive procedures have the disadvantage that they are liable to misclassify stands

(Kershaw, 1961; Gittins, 1965: Ivimey-Cook and Proctor, 1966; Greig-Smith et al, 1967; Hill et al, 1975), but if the classification is regarded as a potentially general one into which further stands are to be placed, they provide and immediate means of doing so by dichotomous keying (Greig-Smith, 1983).

Polythetic divisive classification procedures use information on all species. They begin with all samples together in a single cluster and successively divide the samples into a hierarchy of smaller and smaller clusters until finally, each cluster contains only one sample or some specified small number of samples. Two way indicator species analysis (TWINSPAN) is a polythetic divisive technique (Hill, 1979). The technique is an elaboration of the original technique which clustered samples only (Hill et al. 1975). It uses ordination (Reciprocal averaging) for an over all view of the data, then imposes divisions. Orloci (1967), indicated that polythetic divisive techniques suffer from the disadvantage common in rigid dichotomous divisions; the groups, no matter how homogeneous they are, may break up by chance too early in the process, resulting in classification hierarchies which may contain little information about the natural structure within the population. On the other hand, Lambert et al. (1973), observed that polythetic divisive methods have theoretical advantages in that all the available information is used to make the critical topmost divisions. Further advantages (Gauch and Whittaker, 1981; Gauch, 1982) of this method (TWINSPAN) are: (a) it uses the original vegetation data, rather than a secondary

matrix, (b) it orders the sample sequence in a dendrogram, (c) it also clusters species, (d) it produces a re-order data matrix, and (e) it is economical of computer requirements and these requirements rise only linearly with the amount of data.

Polythetic agglomerative classification techniques use information on all species; they begin with each sample allotted to a cluster with a single member and agglomerate these in a hierarchy of larger and larger clusters until finally a single cluster contains all the samples. These classification procedures have been used much more extensively (e.g. Lance and Williams, 1966; Orloci, 1967; Pritchard and Anderson, 1971; Jancey, 1980; Gauch and Whittaker, 1981) than divisive procedures (Greig-Smith, 1983). Polythetic agglomerative methods, cluster analysis, proceed by scanning the whole data set and by examining the relationships between all possible pairs of individuals ($\frac{1}{2}n(n-1)$) where n= number of samples. At any particular stage the methods fuse individuals or group of individuals which are most similar (or closest) (Sokal and Sneath, 1963; Goodall, 1978). Since polythetic agglomerative procedures cluster on the basis of over all similarity, they are in general less likely to lead to misclassification (Greig-Smith, 1983). Differences between methods arise because of the different ways of defining similarity (or distance) between an individual and a group containing several individuals or group of individuals (Goldsmith and Harrison, 1976; Everitt, 1980). The precise

sorting strategy which is used to direct the path taken by the hierarchy also vary. Several measures of similarity (or distance) function are currently in use and include average linkage clustering, furthest neighbour, group averaging, centroid sorting and minimum variance clustering. All these sorting strategies are considered by Sokal and Sneath (1963), Williams and Dale (1965), Pritchard and Anderson (1971), Goodall (1978), Everitt (1980) and Greig-Smith (1983).

It is now evident that an enormous number of classification techniques have been developed (Whittaker, 1962), and the choice among the techniques depends on the research purpose, size of data, and complexity (Gauch, 1982). Considering the above discussed choices of classification techniques, a cluster analysis, average linkage clustering, which is hierarchical, polythetic and agglomerative, was employed to analyse the data of the present study.

3. MATERIALS AND METHODS

3.1 Vegetation Sampling

A reconnaissance survey of the Harenna forest was made in April 1986 to identify sampling sites. Seventy-five sampling sites, one at every half kilometer interval along Mena - Goba road and one to a three kilometer(s) east or west into the forest, were considered for sampling. A homogeneous square stand of 20 m by 20 m delimited by "Brunton" compass and tape was systematically laid and two samples were taken from each site. The plants in each stand were recorded as present. Trees and shrubs were counted. An estimate of cover abundance for herbs, epiphytes, and lianes, was made using a 1-9 modified Braun-Blanquet (1932) scale (Maarel, 1979; cited in Zerihun 1985). These are:

Scale 1: rare, generally one individual
2: sporadic, with less than 5% cover of the total area.
3: abundant, with less than 5% cover of the total area.
4: very abundant, with less than 5% cover of the total area.
5: 5-12% cover of the total area.
6: 12.5-25% cover of the total area.
7: 25-50% cover of the total area.
8: 50-75% cover of the total area.
9: 75-100% cover of the total area.

Unless identified without doubt, voucher specimens (Lisanework N. 1-121 and Mesfin T. 4819-5614) were pressed and numbered for identification. Most of the specimens were then identified by comparing them with identified specimens

in the National Herbarium in Addis Ababa University and with written descriptions and check lists in various works (e.g. Andrew, 1956; Dale and Greenway, 1961; Burger, 1967; Cufodontis 1952-1972; Thulin, 1983; Friis et al. 1984) on Ethiopian, Sudanese and Tropical East African Flora.

3.2 Environmental Data

The following environmental factors were measured for every sample stand; altitude was recorded using an "Everest" altimeter, slope was measured using a "Clinometer" and "Brunton" compass was used to measure aspect. Soil samples from 10 cm (TS) and 50 cm (SS) depths were taken with a soil auger. However sampling of soil was done from each sample stand one at two kilometers interval from the other. The soil samples were then air dried, rolled and passed through 2 mm sieve for further laboratory analysis.

3.2.1 Soil Analysis

Some physical and chemical properties of the soil samples were studied in the laboratory based on the procedures outlinted by Jackson (1958), Hesse (1971), Juo (1978), Wilde et al. (1978), Cottenie (1980), and Chopra and Knwar (1982).

1. Particle size distribution was determined using the Bouyoucos hydrometer method. Sodium hexametaphosphate and amylacohol were used as dispersing agents and for organic matter destruction, respectively.
2. Soil:water ratio of 1:2.5 with 1N Kcl was used to determine the Hydrogen ion concentration using a glass electrode pH-meter.
3. Conductivity of 1:5 soil-water suspension was determined with a conductivity meter.

4. Colour was determined using the Munsel's colour chart.

5. Organic matter was determined using the Walkely-Black wet oxidation method.

6. Exchangeable bases were extracted with 1N ammonium acetate at pH 7. Sodium and potassium were measured using a flame photometer. Magnesium and Calcium were measured by atomic absorption.

3.3 Statistical Treatment of the Data

3.3.1 Vegetation data

Prior to the analyses of the vegetation data, the plant species recorded from the two sample stands in each sampling site were lumped and considered together; though, it is well realized that lumping under this condition may reduce the homogeneity of sampling. The data for trees and shrubs, which were originally in the form of density values, were converted into presence-absence values for each species. A list of the common species and the stands in which they were recorded is given in appendices 1a and 1b.

In the present study, average linkage clustering procedure was used to classify the vegetation data. The computer program employed was GROUPAGE, a program constructed by Hadju (unpublished) at the Institute of Ecological Botany, Uppsala. It is a polythetic agglomerative procedure in which pairs of entities are combined on the basis of their similarity being highest. In this technique a similarity ratio (SR) function between vegetation samples i and j is defined as:

$$SR_{ij} = \sum_{k}^{m} X_{k,i} \cdot X_{k,j} \Big/ \left(\sum_{k}^{m} X_{k,i}^2 + \sum_{k}^{m} {}_{,j} - \sum_{k}^{m} X_{k,i} \cdot \sum_{k}^{m} X_{k,j} \right)$$

for quantitative data and;

SR_{ij} $m_{i,j}$ $(m_i + m_j - m_{i,j})$ for the presence - absence data; where X_k is the value of the K th variable in the i th and j th samples in quantitative data and $m_{i,j}$ is the value of the m th variable in the i th and j th samples.

After every fusion of the i th and j th samples on the basis of their similarity being highest, a new sample-by-species (nxm) matrix is established with the average of k th (in quantitative data) or m th (in presence-absence data) variables of the previously combined i th and j th samples.

Consider the simple sample-by-species data matrix, with five species and six samples below.

	Samples					
Species	1	2	3	4	5	6
1	6	8	3	1	9	-
2	4	-	8	7	-	8
3	1	5	-	-	1	-
4	2	1	2	-	3	1
5	-	-	-	5	-	2

In the quantitative data, samples 1 and 2 have a similarity ratio of $SR_{1,2}$:

$$(6x8+4x0+1x5x2x1) = \Sigma X_{ki} \cdot X_{kj} = 55$$

$$(6^2 + 4^2 + 1^2 + 2^2) = \Sigma X_{ki}^2 = 57$$

$$(8^2 + 5^2 + 1^2) = \Sigma X_{kj} = 90$$

$$\therefore \quad SR_{1,2} = 55/57 + 90 - 55 = 0.60$$

In the presence-absence data, samples 1 and 2 have a similarity ratio of $SR_{1,2}$:

$$3/4 + 3-3 = 0.75$$

A secondary samples-by-samples similarity ratio matrix computed from the above samples-by-species is shown below:

Quantitative data

SR matrix (x 100)

Sample	1	2	3	4	5	6
1	.	60	67	27	70	37
2		.	18	05	76	01
3			.	63	24	63
4				.	06	85
5					.	02
6						.

Presence-absence data

SR matrix (x 100)

Sample	1	2	3	4	5	6
1	.	75	75	40	75	40
2		.	50	20	100	20
3			.	50	40	50
4				.	20	50
5					.	20
6						.

Since $SR_{4,6}$ = 0.85 is the highest similarity ratio, samples 4 and 6 fuse first. Now, erect a new samples-by-samples matrix on the basis of a new samples-by-species matrix with the average of 4 and 6 as shown below:

Species	Sample 1	2	3	(4,6)	5
1	6	8	3	0.5	9
2	4	-	8	7.5	-
3	1	5	-	0.0	1
4	2	1	2	0.5	3
5	-	-	-	3.5	-

SR matrix in quantative data

Sample	Sample 1	2	3	(4,6)	5
1	.	60	67	33	70
2		.	18	03	76
3			.	74	24
(4,6)				.	04
5					.

At this stage, in the quantitative data, samples/2 and 5 will combine since they show the highest similarity, i.e. 0.76. A similar procedure will be followed for the presence-absence data. These steps will be repeated until all samples are grouped into a signle cluster.

The similarity ratio levels at which fusion of individuals (stands) occurred are given in appendices 2a and 2b.

The analysis on species richness was performed using a computer program CHECK, a program developed by Dr. Zerihun Woldu (unpublished) at the Department of Biology, Addis Ababa University, Ethiopia. Species richness is the number of species in a sample of standard size (Whittaker, 1970). The results are given in appendices 3a and 3b.

3.3.2 Environmental Data

The altitude and slope measured for the replicate stands were averaged and considered to represent the value for a single stand in each sampling site. These values and that for aspect are given in appendix 4. The results of the analysis of the soil samples are presented in appendix 5.

4. RESULTS AND DISCUSSION

4.1 Classification of the Vegetation

The program GROUPAGE was employed to analyse the presence - absence and quantitative vegetation data collected from the Harenna forest. The similarity ratio levels at which ecologically meaningful major clusters show up was determined.

Five major clusters (Fig. 2), designated as A,B,C,D and E were identified at similarity levels between 0.2-0.3 in the presence-absence vegetation data. Similarly, five main clusters (Fig. 3), designated as A', B', C', D', and E' were recognized at similarity levels between 0.1-0.2 in the quantitative vegetation data.

4.2 Comparability of the Clusters

The number of environmental parameters measured, excluding aspect, were averaged for each of the major clusters identified by GROUPAGE, in the presence-absence and quantitative vegetation data. The average values of the measured environmental factors for the clusters identified in both vegetation data sets are presented in tables 2a and 2b. The clusters were then ranked (tables 3a and 3b) on the basis of the mean values of the measured environmental factors. In order to examine the differences and/or the similarities each pair of clusters were then compared using the statistic t-test for each measured environmental parameters. A probability of 0.05 or lower was used

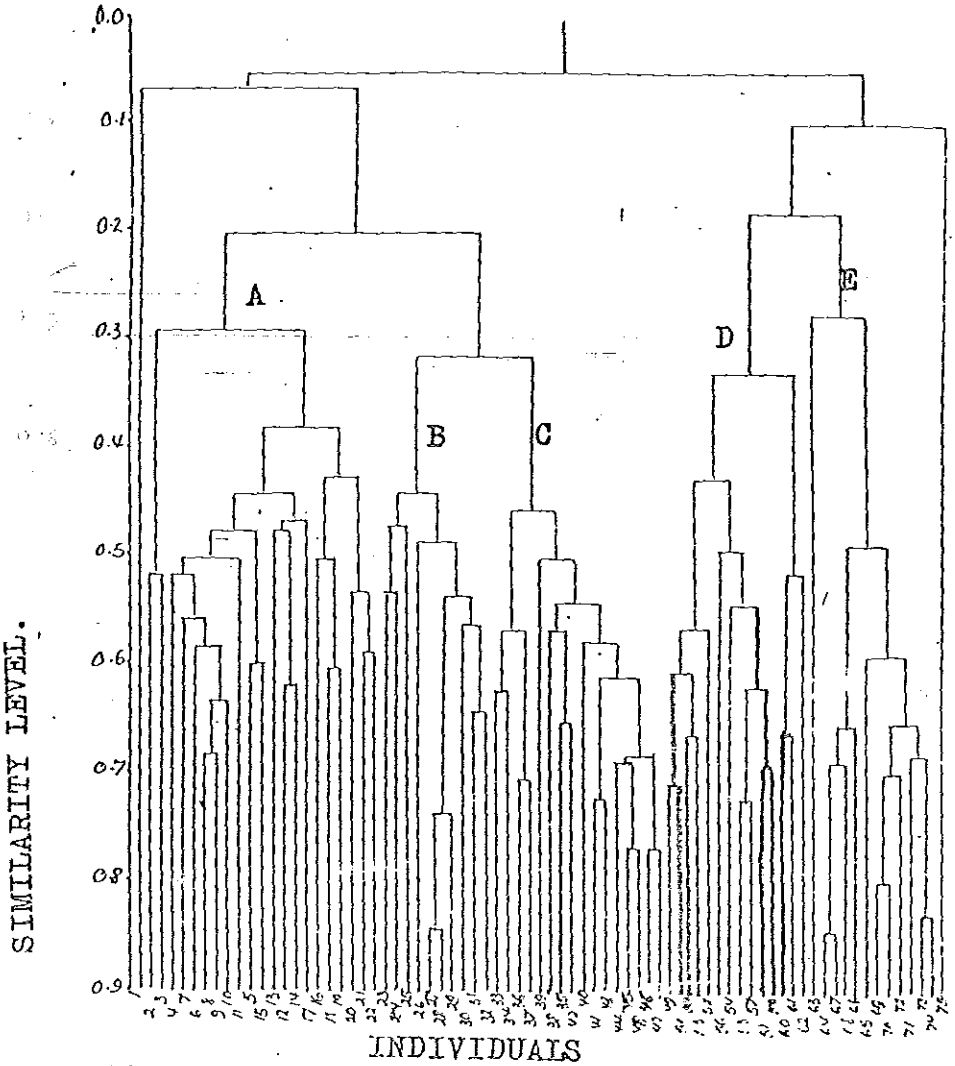

Fig.2. Dendrogram of the presence-absence data set using GROUPAGE.

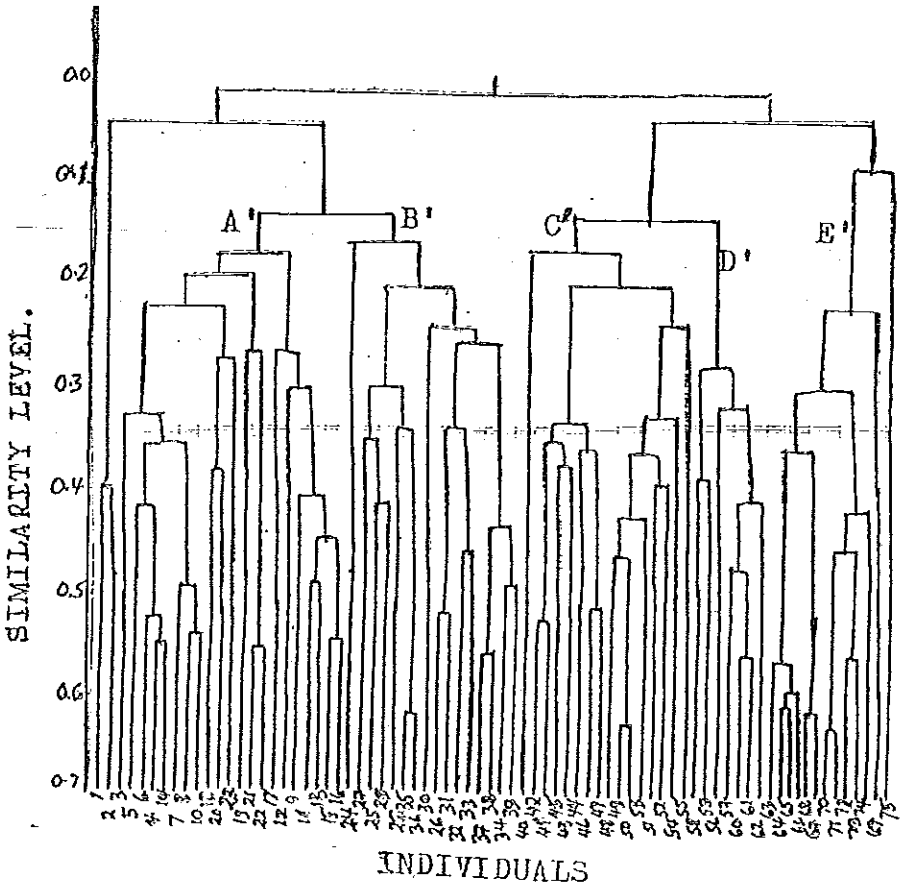

Fig.3. Dendrogram of the quantitative data set using GROUPAGE.

Table 2a. Mean values of the environmental factors for the final homogeneous clusters of the presence-abssence data.

TS = Top soil; SS = Sub soil; O.M = Organic matter

Clusters	Alt. (m)	Slope (°)	Sand %		Silt %		Clay %		Soil colour		O.M. %	
			TS	SS	TS	SS	TS	SS	TS	SS	TS	SS
A	1550	4	33.2	16.0	16.6	11.7	50.2	72.3	6YR3/3	4YR3/2	8.76	2.5
B	1756	5	43.0	24.0	13.0	16.0	44.0	60.0	5YR2/2	5YR3/2	9.13	3.03
C	1998	7.3	35.3	24.6	25.7	23.3	39.0	52.10	5.5YR2/2	5YR3/2	10.17	3.17
D	2477	16	31.0	25.0	42.4	36.2	26.6	38.8	5YR3/2	5YR3/2	11.15	5.54
E	3000	17	35.0	28.0	39.6	38.4	25.4	33.6	5YR3/3	5YR3/3	11.98	5.86

Table 2a Continued

Clusters	pH in KCl		Exchangeable cations in m.eq/100 gm soil										Conductivity mmhos/cm	
			Ca		Mg		K		Na		Sum			
	TS	SS	TS	SS	TS	SS	TS	SS	TS	SS	TS	SS	TS	SS
A	5.9	5.1	30.5	12.8	7.0	4.2	0.87	0.36	0.29	0.23	38.7	17.6	0.593	0.244
B	5.03	4.08	25.0	5.66	6.3	2.0	0.43	0.10	0.27	0.26	32.8	10.0	0.585	0.233
C	5.4	4.7	23.1	13.8	6.7	6.0	1.1	0.42	0.28	0.28	31.2	20.5	0.492	0.162
D	4.4	4.4	13.9	7.7	4.0	3.0	0.9	0.64	0.22	0.20	19.0	11.54	0.42	0.163
E	4.2	4.1	11.0	3.5	3.3	2.0	0.71	0.47	0.23	0.25	15.2	6.02	0.306	0.122

TS = Top soil; SS = Sub soil.

Table 2b. Mean values of the environmental factors for the final homogeneous clusters of the quantitative data.

TS = Top soil; SS = Sub soil; O.M. = Organic matter

Clusters	Alt. (m)	Slope (°)	Sand %		Silt %		Clay %		Soil Colour		O.M. %	
			TS	SS	TS	SS	TS	SS	TS	SS	TS	SS
A'	1550	4	33.2	16.0	16.6	11.7	50.2	72.3	6YR3/3	4YR3/2	8.8	2.5
B'	1825	5	39.69	23.56	19.48	18.01	40.83	58.43	5.3YR2.4/2	5YR3/2	9.3	3.0
C'	2145	12	33.05	25.28	33.54	28.68	33.04	46.04	5.0YR3/2	5YR2.5/2	10.4	4.0
D'	2609	16	29.84	25.73	45.33	41.65	24.72	32.63	5.0YR3/2	5YR3/2	12.5	5.6
E'	3000	17	34.94	27.56	39.62	38.40	25.44	33.59	5YR3/3	5YR3/3	12.0	5.9

Table 2b Continued

Clusters	pH in KCl		Exchangeable cations in meq/100 gm soil										Conductivity mmhos/cm	
			Ca		Mg		K		Na		Sum			
	TS	SS	TS	SS	TS	SS	TS	SS	TS	SS	TS	SS	TS	SS
A'	5.9	5.1	30.5	12.8	7.0	4.2	0.87	0.36	0.29	0.23	38.7	17.6	0.593	0.244
B'	5.4	4.6	25.6	11.50	6.90	3.8	1.00	0.28	0.29	0.29	33.8	15.9	0.60	0.201
C'	5.0	4.4	23.5	12.80	9.97	5.3	0.92	0.53	0.26	0.23	34.7	18.9	0.37	0.169
D'	4.04	4.2	0.83	0.00	1.70	1.1	0.56	0.63	0.19	0.19	3.2	1.9	0.48	0.127
E'	4.4	4.1	11.0	3.50	3.30	1.8	0.71	0.47	0.23	0.25	15.2	6.0	0.31	0.122

TS= Top soil; SS= Sub soil

Table 3a. Ranks of the final homogeneous clusters of the presence-absence data based on the mean values of the environmental parameters.
TS= Top soil; SS=Sub soil; O.M.= Organic matter

			Sand		Silt		Clay		O.M.		pH	
Clusters	Alt.	Slope	TS	SS	TS	SS	TS	SS	TS	SS	TS	SS
A	5	5	4	5	5	5	1	1	5	5	1	1
B	4	4	1	4	4	4	2	2	4	4	2	2
C	3	3	2	3	3	3	3	3	3	3	3	3
D	2	2	5	2	1	2	4	4	2	1	4	4
E	1	1	3	1	2	1	5	5	1	2	5	5

Table 3a. Continued.

	Ca		Mg		K		Na		Conductivity	
Clusters	TS	SS	TS	SS	TS	SS	TS	SS	TS	SS
A	1	2	1	2	3	4	1	4	1	1
B	2	4	3	4	5	5	3	2	2	2
C	3	1	2	1	1	3	2	1	3	3
D	4	3	4	3	2	1	5	5	4	4
E	5	5	5	4	4	2	4	3	5	5

Table 3b. Ranks of the final homogeneous clusters of the quantative data based on the mean values of the environmental parameters.
TS=Top soil; SS=Sub soil; O.M.=Organic matter

			Sand		Silt		Clay		O.M.		pH	
Clusters	Alt.	Slope	TS	SS	TS	SS	TS	SS	TS	SS	TS	SS
A'	5	5	3	5	5	5	1	1	5	5	1	1
B'	4	4	1	4	4	4	2	2	4	4	2	2
C'	3	3	4	3	3	3	3	3	3	3	3	3
D'	2	2	5	2	1	1	4	5	1	2	4	4
E'	1	1	2	1	2	2	5	4	2	1	4	5

Table 3b. Continued

	Ca		Mg		K		Na		Conductivity	
Clusters	TS	SS	TS	SS	TS	SS	TS	SS	TS	SS
A'	1	1	2	2	3	5	1	2	1	2
B'	2	3	3	3	1	4	1	1	2	1
C'	3	2	1	1	2	1	2	3	3	4
D'	4	5	5	5	5	2	4	5	4	3
E'	5	4	4	4	4	3	3	4	5	5

Table 4a. Summary of the comparison of the clusters of the presence-absence data, using t-test based on mean values of the environmental parameters (The numbers in the table represent the total significant contrast each cluster showed).
TS=Top soil; SS=Sub soil; O.M.=Organic matter

			Sand		Silt		Clay		O.M.		pH	
Clusters	Alt.	Slope	TS	SS	TS	SS	TS	SS	TS	SS	TS	SS
A	4	3	2	4	3	4	3	4	2	2	4	3
B	4	2	3	1	3	3	2	3	1	2	2	2
C	4	3	0	1	4	3	1	4	0	2	3	2
D	4	3	3	1	3	3	2	3	1	3	2	2
E	4	3	2	1	3	3	2	3	2	3	3	4
Total SSig.Con.	20	14	10	8	16	16	10	17	6	12	14	13

Table 4a. Continued.

	Ca		Mg		K		Na		Conductivity	
Clusters	TS	SS	TS	SS	TS	SS	TS	SS	TS	SS
A	3	2	2	3	0	0	1	1	1	1
B	1	1	1	2	0	2	0	0	1	1
C	2	0	1	3	0	3	1	2	0	1
D	2	0	1	1	0	2	2	1	0	0
E	3	2	3	3	0	1	0	0	2	2
Total Sig.Con.	12	5	8	12	0	8	4	4	4	5

Table 4b. Summary of the comparison of the clusters of the quantitative data on mean values of the environmental parameters (The numbers in the table represent the total significant contrast each cluster showed).

TS=Top soil; SS=Sub soil; O.M.=Organic matter.

			Sand		Silt		Clay		O.M.		pH	
Clusters	Alt.	Slope	TS	SS	TS	SS	TS	SS	TS	SS	TS	SS
A'	4	3	1	4	3	4	4	4	2	1	4	3
B'	4	3	2	1	3	4	3	4	2	2	2	0
C'	4	2	1	1	3	3	1	3	0	1	2	1
D'	4	2	1	2	3	2	2	2	2	1	4	1
E'	4	2	0	1	2	3	2	3	2	3	3	1
Total Sig.Con.	20	12	5	8	14	16	12	16	8	8	15	6

Table 4b. Continued.

	Ca		Mg		K		Na		Conductivity	
Clusters	TS	SS	TS	SS	TS	SS	TS	SS	TS	SS
A'	2	2	3	2	0	0	1	2	2	2
B'	2	2	3	1	0	2	0	3	2	2
C'	2	2	4	2	0	1	0	2	1	0
D'	4	3	4	2	0	0	0	1	1	2
E'	4	3	4	3	0	1	1	0	2	2
Total Sig.Con.	14	12	18	10	0	4	2	8	8	8

as a level of significance in the t-test. The results are given in appendices 6a to 6k and 7a to 7k. Tables 4a and 4b show a summary of significant contrasts each cluster showed using the t-test for the measured environmental factors.

4.3 Interactions in the Ecosystem

The Harenna forest starts from 1500 m and extends northwards to 3250 m. The natural vegetation is varied structurally and compositionally, and this, for the most part is due to the great variation in altitude. The results of the presence-absence and quantitative data, using the program GROUPAGE, revealed that the stands were partitioned into five major culsters that contrasted markedly in altitude.

An arrangement of the clusters in increasing average altitude give the order A,B,C,D, and E in the presence-absence data and A', B', C', D', and E' in the quantitative data. The position of the identified clusters with respect to altitude is shown in Figs. 4 and 5.

Altitude is an important environmental factor which, by affecting temperature, radiation, moisture, atmospheric pressure, influences the grwoth and development of plants and the distribution of vegetation (Toumey, 1947; Hedberg, 1964). Daniel (1986) gives an account of altitudinal gradients (with increasing altitudes) of mean monthly values of temperature, radiation and moisture during the wettest and driest months in Bale mountains. According to this author and Hillman (1986), decrease in temperature, radiation, vapour pressure, and increase in moisture occur with rise in elevation. The effects of these conditions in the Harenna forest

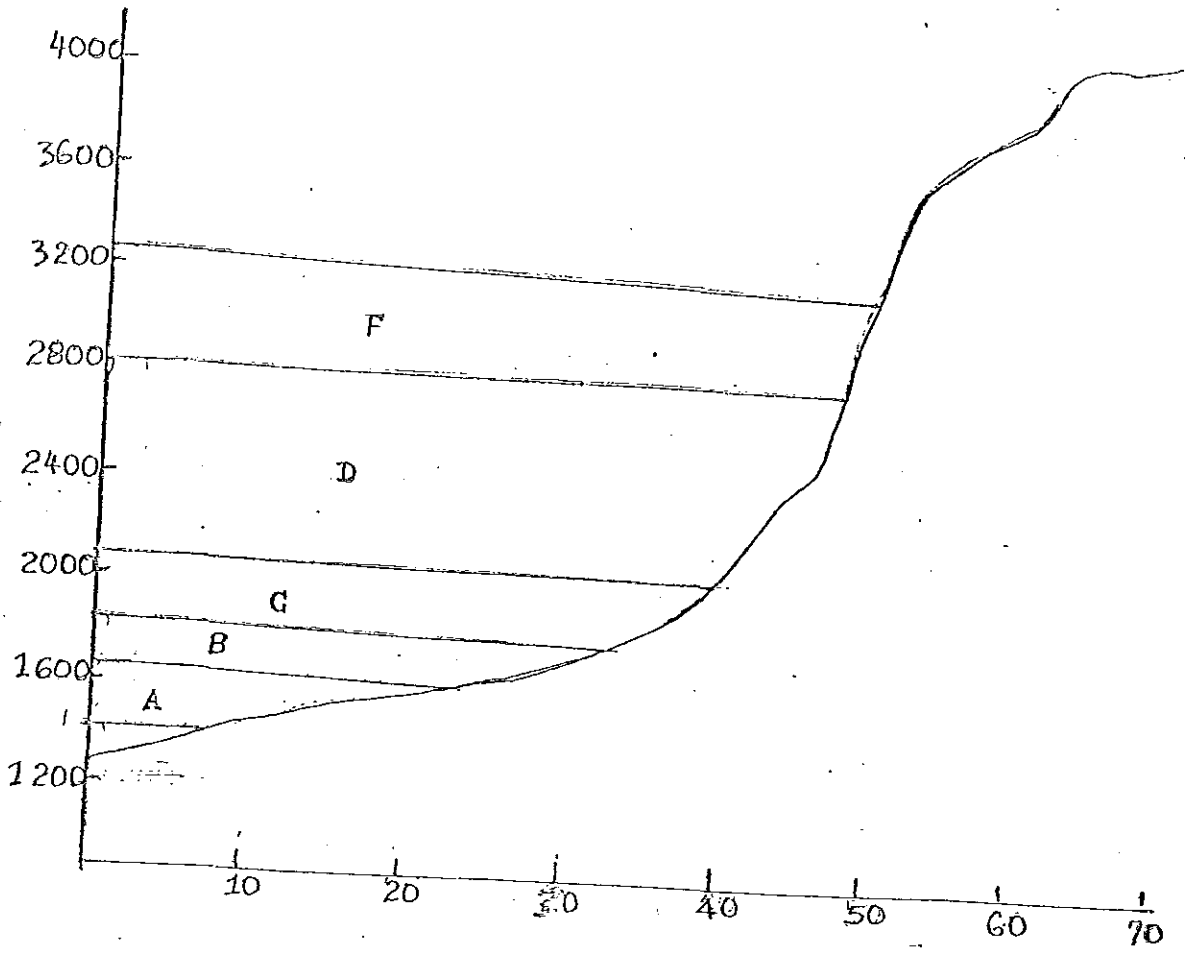

Fig.4. Altitudinal ranges of the final homogeneous clusters identified by GROUPAGE (presence-absence data). (Vertical axis: altitude in meters; horizontal axis: distance in Km.)

Cluste	Altitude(m)
A	1500-1660
B	1660-1840
C	1840-2160
D	2160-2800
E	2800-3250

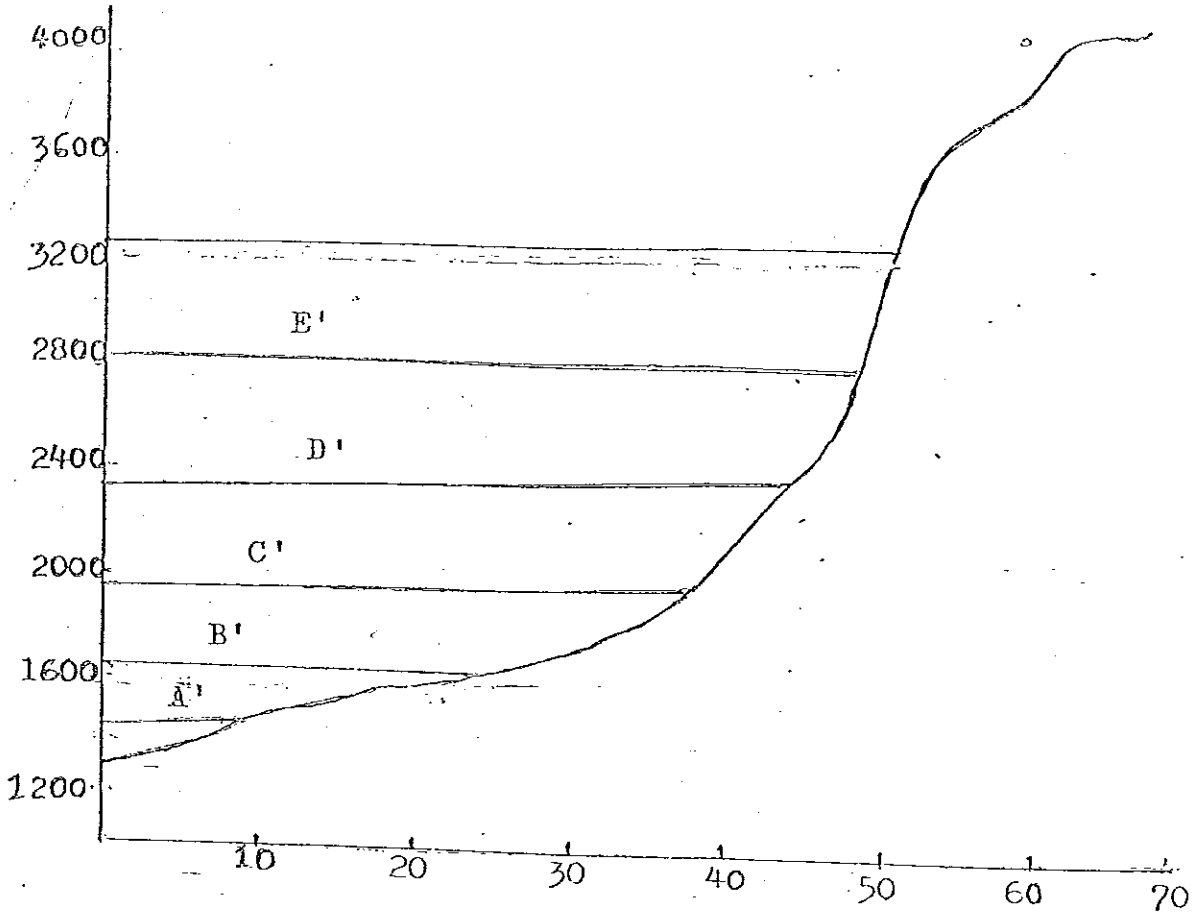

Fig.5. Altitudinal ranges of the Final homogeneous clusters identified by GROUPAGE (quantitative data). (Vertical axis: altitude in meters; horizontal axis: distance in Km.).

Clusters	Altitude (m)
A'	1500-1660
B'	1660-1980
C'	1980-2390
D'	2390-2800
E'	2800-3250

have resulted in an overall decrease in species diversity, vegetation cover and the growth forms of plant species with rise in altitude.

The result of the presence-absence data, using the program CHECK, showed a decrease in the species diversity with rise in altitude. Analysis of the quantitative data, on the other hand, indicated an increase in species richness with rise in elevation. The general tendency, however, is a decrease in species diversity along increasing altitudinal gradient. It appears, therefore, that the tree and shrub species increase toward lower elevations and warmer climates; while herbaceous plants, epiphytes and lianes increase toward higher elevation and wetter climates. Thus, along with a change in diversity there is a change in competition in stands with the gradual transition from interspecific to intraspecific competition. This has some consequences on the regeneration pattern and stand development which needs different silvicultural treatments (Uhling, 1986). Table 5 gives the minimum and maximum record of species in the presence-absence and quantitative data sets.

Table 5. Minimum and maximum number of species in the presence-absence and quantative data.

Cluster		A(A')	B(B')	C(C')	D(D')	E(E')
Presence	min	12	21	17	12	2
absence data	max	28	28	24	21	13
quantitative	min	6	10	11	10	15
data	mzx	17	17	19	25	27

In the region of the Harenna forest mist cover is a common phenomenon above 2300 m during the wet season which lasts for about eight months. The abundance of the epiphytic plants is, therefore, related to this condition. It is evident that incident light intensity is decreased in mist covered forests, but for the undergrowth development this effect may largely be offset by the lower and generally more open canopy of the montane forest type at higher altitudes (Richards, 1952; cited in Grubb, 1971).

Slope is one of the most important environmental elements in any landscape. The marked effect of slope is in its influence on the run-off and drainage and consequently upon the depth as well as nutrient and water content of the soil. The Harenna escarpment falls in altitude to the south from 3800 m to 2300 m within a distance of c.10 km. The slope from 2300 m upto the lower limit of the forest is gentle. As a result slope is expected to be positively correlated with altitude.

An arrangement of the clusters in increasing mean values of slope gives the order A,B,C,D, and E and A',B',C',D', and E' in the presence-absence and quantitative data, respectively. The results of the vegetation data revealed that clusters E, E' and D,D' are located on steep slopes. The steeper the slope, the more subject to removal through run-off become soil particles together with nutrients from the surface layers during wet seasons (Toumey, 1947; Thompson and Troech, 1978). Steep slope promotes drainage, increases aeration and encourages red colouration. According to

Moss (1968), well drained soils are distinguished by downward leaching by oxygenated water, and at least for the greater part of the year oxidizing conditions occur throughout the profile. Nevertheless, slope alone may not influenced drainage and initiation of red coloutation. The impact of parent material must also be taken into consideration. Buckman and Brady (1969) suggest that if a soil is underlain by impermeable rock type, drainage could be hindered. As a result, slope together with the rock type determine the type of vegetation in the Harenna forest.

An arrangement of the clusters based on increasing mean values of the organic matter gives the order A,B,C,D, and E for top soil values and A,B,C,E, and D for subsoil values in the presence-absence data. The ranking of the clusters resulting from the quantitative data based on increasing average values of organic matter showed the order A',B',C',D' and A',B',C',D', and E' for top and sub soil values, respectively.

In the area of the Harenna forest the amount of organic matter in the soil increases with altitude and slope. This increase could be attributed to a decrease in temperature, high rainfall and an increase in the frequency of mist which renders mineralization of the organic matter with increasing altitudinal gradient. Grubb (1971), on the interpretation of 'Massenerhebung' effect, suggested that the mineralization of the humus decreases with the lowering of the mean temperature or increasing of the soil water content.

Moreover, low pH of the soil will reduce microbial activity, thus retarding mineralization of organic matter (Buckman and Brady, 1969). PH is consistently lower in the wetter than the drier forest types. Limitation of bacterial activity by low pH and accompanying calcium deficiency, according to Etherington (1975), slows the rate of organic matter decomposition so that acid soils tend to accumulate a thick, superficial mat of undecomposed organic matter. Increasing wetness also inhibits oxygen diffusion in the soil, encourages anaerobiosis and slows decomposition. According to Etherington (1975), well drained soils are often of low organic content and show little litter accumulation but, if soils are continually wet or nutrient deficient then accumulation of organic matter may result.

Variation in soil pH essentially does not directly influence plant growth. The very marked differences between the vegetation types inhabiting low pH and high pH soils seem to arise in their responses to mineral nutrition and organic matter decomposition (Kostler, 1956; Buckman and Brady, 1969; Etherington, 1975).

An arrangement of the clusters based on increasing mean values of pH in the presence-absence data gives the order E,D,C,B, and A for both top and sub soil values. The ranking of the clusters based on increasing average values of the pH for the top and sub-soil values gives the order E',E',C',B' and A' in the quantitative data. Exchangeable bases which have been replaced from the collodial complex or which have

been dissolved by percolating acids of organic and inorganic compounds are removed in the drainage waters. This is a normal process in areas with steep slopes, high permeability and high rainfall; and this encourages the development of acidity in an indirect way by removing those exchangeable bases which might compete with acidic cations. According to Buckman and Brady (1969), soils having low pH values are characterized by relatively high concentration of the acidic cations H^{+}, Al^{+++}, Fe^{+++} and Mn^{++} and low exchangeable bases; Ca^{++}, Mg^{++}, Na^{+} and K^{+}. The optimum pH for plant growth is related to soil texture. It is rather low in organic soils and for mineral soils it rises with increasing clay content. In the study area, the forest soil under its protective forest cover is delicately balanced with gradual breakdown of organic matter being offset by the steady accumulation of organic material from the vegetation cover. This continual breakdown and accumulation of organic matter together with a considerable leaching of mineral nutrients lead to an increment of the acidity of the forest soil with increasing altitude. According to Tewolde (1975), the average pH, however, is not necessarily indicative of the pH to which the plant is subjected, as in some habitats species can grow and develop by keeping their roots at different levels of the soil profile. Thus, the value of the soil's pH can be judged as a sign of its exchangeable cation saturation. Conductivity, even more largely than pH, is indicative of the total amount of water soluble salts, which are important plant nutrients (Thompson and Troech, 1978).

An arrangement of the clusters based on increasing average values of conductivity in the presence-absence data gives the order E,D,C,B and A for top and sub soil values. The ranking of the clusters based on increasing mean values of conductivity in quantitative data gives the order E',C', D', A' and B' for top soil and E',D',C',B', and A' for sub soil values. Steeper slopes, higher rainfall and permeability cause greater leaching of exchangeable bases from the soil than their addition by rock weathering or down-wash from higher ground. Thus low soluble salt concentration is expected with increasing altitude and slope.

Soil texture by influencing soil-water relationships, aeration and penetrability through its relationship with interparticle pore space, is an important environmental factor that determines the concentration of the soil mineral nutrients. The results of the textural analysis of the soils of the Harenna forest revealed that clay particles prevail at lower altitudes, silt at higher altitudes and sand particles are variable along the altitudinal gradient. The relation to vegetation types of physical properties of soils is partly due to unequal distribution of major rock types within the rainfall zone (Hall and Swaine,1976). Generally, the texture of the soils of the Harenna forest ranges from clay loam to silty clayloam with increasing elevation. The dominance of clay particles at lower altitudes reflects the effect of chemical weathering. Chemical weathering (Buckman and Brady, 1969), is more rapid in regions of high annual temperatures, especially if sufficient moisture is present to encourage

decomposition. Clay fraction is the main source of many plant nutrients and cation exchange activity. Consequently, a positive correlation is expected between clay particles and cation concentration.

The chemical analysis of exchangeable cations, such as Ca, Mg, K and Na showed that the soils of the Harenna forest are rich in basic exchangeable cations of which calcium is the most prevalent. It constitutes 69.29 to 76.05% and 67.45 to 72.8% of the total basic exchangeable cations in presence-absence and quantitative data sets, respectively. The parent material, which is mainly basalt, may explain the relative abundance of the basic exchangeable cations in the soils of the Harenna forest. According to Weinert and Mazurek (1984), most of the soils of the Bale mountains are relatively young, being developed on volcanic and pyroclastic rocks, such as trachyte, porphyry, tuffs, ignimbrites and obsydian, and rich in plant available nutrients.

There is little or no variation in soil colour of the analysed soil samples from the area of the Harenna forest. In most of the soil samples the hue (the cominant spectral colour or quality) is uniformly 5 YR. The value (the apparent lightness as to absolute white) ranges from 2-3, and the chroma (the apparent degree of divergence from neutral grey to white) ranges from 2-4. There is no marked variation in soil colour between the top and sub soils, both exhibiting a general soil colour of dark reddish brown. Soil colour

which is related to soil minerology, soil organic matter and climate is an important indicator of drainage condition of the soil and hence for vegetation development. According to Tewolde (1975), the shallower the reddest soil colour depth, the more water logged is the soil. On the other hand, the lower the value of the soil colour hue, and the deeper the reddest colour from the surface, the better drained is the soil.

From the foregoing discussion, the interaction of the environmental factors suggest that with increasing elevatio, slope and organic matter increase while pH, conductivity, exchangeable basic cations and clay particles decrease. Consequently, the distribution of the vegetation types and their differences in floristic composition are attributed to the variation in altitude, upon its effect on the climate, and physical and chemical properties of the soil.

5. CONCLUSIONS AND RECOMMENDATIONS

In the present study, the analyses of both the presence-absence and quantitative data from 75 sites revealed that the vegetation of the Harenna forest can be categorized into five distinct vegetation types depending upon altitude. These vegetation types show close similarities in their distribution with increasing elevation; and these agree with the vegetation types described in the introduction. Accordingly, the vegetation types identified in the area of the Harenna forest form an altitudinal series starting from 1500 m., represented by Podocarpus forest, Podocarpus-Aningeria forest, Aningeria forest, Schefflera-Hagenia forest and Hypericum-Erica forest, upto 3250 m (tree line). The variation in floristic composition among vegetation types is primarily due to differences in moisture with increasing altitude (See also Hillman, 1986).

The Harenna forest is one of the few natural forests remaining relatively undamaged in Ethiopia. The soils of the Harenna forest have remained under the protective forest cover to be well developed. The soils are characterized by being slightly to strongly acidic, well drained, with good structural stability, high organic matter and much plant nutrients.

It is indicated in the introduction that soil erosion is the greatest single menace emerging from the current landuse practices in the country. This has mainly been the result of indiscriminate clearing of the vegetation. In the

area of the Harenna forest the soil is well protected in-spite of the prevailing steep slopes. Thus, the natural vegetation appears to serve in maintaining the biogeochemical cycle of the area. Grazing, however, has been observed in the Hypericum - Erica and the Podocarpus forests zones. This will have a pronounced effect on the regeneration of the forests and needs checking. Besides, the recently constructed Mena - Goba road has encouraged the local inhabitants to shift from the pastoral to settled agricultural practices. The implication of this is already evident in the vicinity of Rira village. The extraction of timber, though at its initial stages, is mainly limited to the areas of the Podocarpus and Podocarpus - Aningeria forests zones. These forests are known to consist of commercially valuable plant species and also Coffea arabica, which, if conserved, could act as an important gene reserve. Forest trees are vast reservoirs of mineral nutrients. The uncontrolled exploitation of forest means a tremendous depletion of the nutrient reserve of the area.

The Harenna forest is within the proposed Bale Mountains National Park. The forest should be conserved for the following reasons:

1. The Harenna forest covers the entire catchment area of several rivers and streams which are of great significance to the people living in the lowland areas. Some development projects have already been proposed, based on the perennial water supply from the catchment area; e.g. proposal to establish a hydro-electric power station, irrigation and water supply (Johansson and Ohlsson, 1986).

2. The Harenna forest could be considered as gene reserve and natural regeneration area for several economically important plant species.

3. The Harenna forest is probably the last remaining montane forest in the country with distinct vegetation zones that could serve for scientific research work. According to Friis et al (1984), a number of plant species recorded from the Harenna forest were found to be new to the country and/or to science.

4. The Harenna forest provides habitat for a number of unique wild animals (Hillman, 1986) which are part of the country's natural heritage.

However, any conservation program implemented should cater for the local people, and only then will the practice be realized. Obviously, this calls for better landuse planning as a means to avoid conflicts of interest between the future utilization of the forest and other development activities.

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Appendix 1a

Vegetation Data Collected from the Harenna Forest

I. Trees and Shrubs

Voucher No.	Scientific name (Family name CAPITALIZED)	Stand No.
5	Adhatoda schimperiana Nees. (ACANTHACEAE)	24,25,26,27,29, 30
6	Alangium chinense (Lour.) Harms (ALANGIACEAE)	23,24,30,31,33.
7	Allophylus abyssinicus (Hochst.) Radlk. (SAPINDACEAE)	18,19,20,22,24, 27,28,29,30,31, 32,33,34,35,38, 39,41,42,43,44, 45,46,47,48,49, 50,51,52,53,54, 55,57,58,59.
8	Allophylus macrobotrys Gilg. (SAPINDACEAE)	3,4,6,8,10,11, 18,19,23,24,25, 27,28,29,31,32.
9	Aningeria adlofi-friedericii (Engl.) Robyns & Gilbert (SAPOTACEAE)	23,24,25,27,28, 29,33,34,35,36, 37,38,39,40,41, 42,43,44,45,46, 47,48.
10	Apodytes dimidiata E. Mey. ex. Benth. (ICACINACEAE)	25,26,30,31,32.
---	Arundinaria alpina K. Schum. (POACEAE).	52,53,54,55,56, 57,58,59,60,61, 62,69.
13	Bersema abyssinica Fresen (MELIANTHACEAE)	2,3,4,5,6,7,8,9, 10,11,12,13,14, 15,16,17,18,19, 20,23,24,26,27, 28,29,30,31,32, 33,35,36,37,38, 39,40,41,42,43, 44,45,46,47,48, 49,50,51,52,53, 54,55,56,57,58, 59,60,61,62,64, 66,67.

Appendix 1a Continued

Voucher No.	Scientific name (Family name CAPITALIZED)	Stand No.
14	Brucea antidysenterica J. M. Mill (SIMAROUBACEAE)	4,5,7,9,12,14,15, 16,17,20,24,27,28, 29,30,31,32,33,34, 35,36,37,38,39,40, 41,42,43,46,47,49, 50,51,52,53,54,55, 56,57,59,60,61,62, 64,66,67,69.
17	Calpurnia aurea (Ait) Benth. (LEGUMINOSAE)	2,9,10,14,16,18.
5315	Canthium oligocarpum Hiern (RUBIACEAE)	40,41,43,44,46,47, 48,49,50,51,52,53, 57,59,60,61,62,64, 65,67.
18	Carissa edulis (Forssk.) Vahl. (APOCYNACEAE)	1,4,5,6,7,8,9,11, 14,15.
19	Cassipourea malosana (Bak.) Alston. (RHIZOPHORACEAE)	23,26,27,28,29,30, 31,32,33,34,35,36, 37,38,39,40,41,42, 43,44,45,46,47,48. 49,50,51,52,53,54, 55,56,57,58,59.
20	Celtis africana Burm. f (ULMACEAE)	2,3,4,5,6,7,8,9,10,11, 12,13,14,15,16,17, 18,19,20,21,22,23, 24,25,26,27,28,29, 30.
21	Celtis gomphophylla Bak. (ULMACEAE)	5,7,8,9,10,11,15, 16,18,19.
23	Citrus aurantium L. (RUTACEAE)	2,3,4,5,6,7,8,9, 10,11,12,13,15,16, 18,21.

Appendix 1a Continued.

Voucher No.	Scientific name (Family name (CAPITALIZED)	Stand No.
25	Coffea arabica L. (RUBIACEAE)	3,4,5,6,7,8,9,10, 11,12,13,14,15,16, 17,18,19,21,22,23, 24,25,26.
26	Combretum aculeatum Vent (COMBRETACEAE)	1.
27	Combretum collinum Fresen (COMBRETACEAE)	1.
28	Combretum molle R.Br. ex. G. Don (COMBRETACEAE)	1
30.	Cordia africana Lam (BORAGINACEAE)	8,9,10,11,12,14, 15,20,21,22,23.
--	Croton macrostacys Del. (EUPHORBIACEAE)	1,2,3,5,6,7,8,9,10, 11,12,13,14,17,18, 19,20,21,22,23,24, 25,26,27,28,29,30, 31,32,35,36,37,38, 40,41,42,43,44,45, 46,47,48,49,50,51, 52,53,54,58,59,64.
31	Crotalaria agatiflora Schweinf. (LEGUMINOSAE)	51,53,55,56,57,59, 60,61,66,67,68.
35	Dichrostachys cinerea (L) Winght & Arn. (LEGUMINOSAE)	1.
36	Diospyros abyssinica (Hiern.) F.White. (EBENACEAE)	2,4,5,6,7,8,9,10, 11,14,16,17.
5346	Discopodium penninervium Hochst. (SOLANACEAE)	63,64,67,68,69,70, 71,72,73,74.

Appendix 1a Continued.

Voucher No.	Scientific name (Family name CAPITALIZED).	Stand No.
4924	Dombeya torrida (J.F. Gmel.) Bamps. (STERCULIACEAE)	49,50,51,52,54,55, 56,58,59,60,61,66, 72.
117	Dracaena afromontana Mildbr. (AGAVACEAE)	39,40,41,42,43,44, 45,47,48,49,50,51, 53,55,56,57.
118	Dracaena steudneri Engl. (AGAVACEAE)	32,33,34,35,36,37, 38,40,41.
38	Ehretia cymosa Thonn (BORAGINACEAE)	1,2,4,7,10,17,19, 20,21,22,23,24,26, 29,30,31.
---	Erica arborea L. (ERICACEAE)	63,64,65,66,67,68, 69,70,71,72,73,74, 75.
5047	Erythrina brucei Schweinf (LEGUMINOSAE)	44,45,46,47,48,49, 50,51,52,53.
40	Erythrococca sp. (EUPHORBIACEAE)	10,11,12,13,14,15, 17,19,21,22,24.
43	Euclea schimperi (A.Dc.) Dandy (EBENACEAE)	1,2.
41	Fagaropsis angolensis (Engl. Dele (RUTACEAE)	2,6,8,12,13,14,15.
42	Ficus exasperata Vahl. (MORACEAE)	26,27,28,29.
5313	Ficus sur Forsk. (MORACEAE).	36,37,39,48,52,54, 56.
44	Ficus thonningii Blume	16,18,20,21,23,24, 26.

Appendix 1a Continued.

Voucher No.	Scientific name (Family name (CAPITALIZED)	Stand No.
45	Filcium decipiens (Wight & Arn.) Thw. (SAPINDACEAE)	2,3,4,6,10,15,16, 17,18,19.
46	Flacouritia indica (Burm.f.) Mern (FLACOURTIZCEAE)	2,3,4,7,8,9,10,11.
4852	Galiniera coffeoides Del. (RUBIACEAE)	18,19,20,21,22,23, 24,25,26,27,30,32, 33,36.
---	Hagenia abyssinica (Bruce) J.F. Gmel. (ROSACEAE)	49,50,51,52,53,54, 55,56,57,58,59,60, 61,62,64,65,66,67, 68,69,70,71,72,73, 74.
50	Hypericum revolutum Vahl (HYPERICACEAE)	55,61,62,63,64,65, 67,68,69,70,71.
4842	Ilex mitis (L.) Radlk (AQIFOLIACEAE)	55,56,57,58,59,60.
58	Lepidotrichilia volkensii (Gurke) Leroy. (MELIACEAE)	16,19,20,23,25,26, 27,28,29,30,31,32, 33,34,35,36,37,38, 39,40,41,42,43,44, 45,46,47,48,49,50, 51,52,53,54,55,56, 57,58,59,60,61.
59	Linociera giordani chiov. (OLEACEAE)	26,30,32,33,34,36, 37.
60	Lobelia giverroa Hemsl. (CAMPANULACEAE)	31,32,33,34,35,36, 37,38,42,52,53,56, 58,59.
64	Macaranga capensis (Baill.) Sim. (EUPHORBIACEAE)	6,7,9,10,11,12,14, 17,24,25,26.27,28, 32,33,34,36.

Appendix 1a Continued

Voucher No.	Scientific name (Family name (CAPITALIZED)	Stand No.
65	Margaritaria discoidea (Baill.) Webster (EUPHORBIACEAE)	5,6,7,8,9,10.
5309	Maytenus arbutifolia (Hochst. ex. A. Rich) Wilczek (CELASTRACEAE)	1,2,11,13,14,15,16, 17,18,19,20,21,23, 24,26,29,30,31,32, 33,36,37,41,42,43, 44,45,46,47,48,50, 51,53,54,55,58,59, 60,61,62,70.
5268	Maytenus gracilipes (Welw. ex. Oliv.) Exell. sub. sp. arguta (Loes.) Sebsebe (CELASTRACEAE)	27,28,29,30,31,32,33, 34,35,36,37,39,42,44, 45,48,51.
5148	*Maytenus sp. aff. buchansnii (Loes.) Wilczeck (CELASTRACEAE)	46,48,49,50,52,55, 56,57,58,60,64,65, 66,67,68.
4864	Maytenus undatus (Thunb.) Blakelock. (CELASTRICEAE)	17,18,21,23,27,30, 34,35,36,37,39,41, 47,50.
67	Millettia ferruginea Blakelock. (CELASTRACEAE)	17,18,21,23,27,30, 34,35,36,37,39,41, 47,50.
66	Mimusops kummel Bruce ex. A.Dc. (SAPOTACEAE)	5,13,15.
5318	Nuxia congesta Fresen (BUDDLEJACEAE)	54,55,56,57,58,59, 60.

Appendix 1a Continued.

Voucher No.	Scientific name (Family name (CAPITALIZED)	Stand No.
69	Ocotea kenyensis (Chiov.) Robyns & Wilczek (LAURACEAE)	6,7,9,11,12,13, 14,16,17,18,19, 20,21,22,24,25, 26,27,28,29,30, 31,32,33,34,35.
70	Olea hochstetteri Baker (OLEACEAE)	2,4,6,8,9,10,12, 14,16,19,22,26, 29.
71	Olea welwitschii (Knobl.) Gilg & Schellenb. (OLEACEAE)	2,3,4,5,7,11,13, 15,17,18,19,20,21.
73	Oxyanthus speciosus Dc. (RUBIACEAE)	4,5,8,9,10,11,15, 16,17,18,19,20,22, 23,24,25,26,27,28, 29,30,31,32,33,34, 35,36,37,40,41,42, 44,46,47,48,49,50, 51,52,53,54,56,57, 58,59,60,61.
--	Podocarpus gracilior Pilg. (PODOCARPACEAE)	2,3,4,5,6,7,8,9, 10,11,12,13,14,15, 16,17,18,19,20,21, 22,23,24,25,26,27, 28,29,30,31,32,33, 34,35,37.
80	Polyscias fulva (Harms.) (Harms. (ARALIACEAE)	2,3,5,6,7,8,9,10, 11,12,14,16,21,22, 24,25,26,27,28,29, 30,31,32,34,36,38, 39,49,51.
81	Psychotria orophila Petit (RUBIACEAE)	34,35,36,40,42,43, 44,45,46,47,48,53.

Appendix 1a Continued.

Voucher No.	Scientific name (Family name CAPITALIZED)	Stand No.
82	Psydrax schimperiana (A.Rich.) Bridson (RUBIACEAE)	4,5,6,7,8,9,10,11, 12,14,15,17,18,19, 22,30,40,42,43.
5038	Prunus africana (Hook.f.) Kalkn. (ROSACEAE)	17,20,23,24,25,27, 28,29,31,32,34,35, 37,38,39,40,41,42, 43,44,45,46,47,48, 49,51,52,54.
84	Rapanea simensis (Dc.) Mez (MYRSINACEAE)	60,61,62,63,64,65, 66,67,68,69,70,71, 72,74.
85	Rhamnus prinoides L'Herit (RHAMNACEAE)	2,3,4,5,11,12,21,27.
86	Rhus natalensis Krauss (ANACARDIACEAE)	1,2.
87	Rhytigynia neglecta (Hiern.) Robyns (RUBIACEAE)	2,3,4,5,6,8,10,15, 18.
5039	Rubus apetalus Poir. (ROSACEAE)	4,10,12,22,26,32, 44,55,57,58,59,61, 62,63.
88	Rubus steudneri Schwienf. (ROSACEAE)	2,3,11,14,40,44,49, 51,54,56,57,58,59, 62,66,69,70,72.
92	Schefflera abyssinica (A. Rich.) Harms. (ARILACEAE)	26,27,28,29,32,33, 34,35,36,37,38,39, 41,42,43,44,45,46, 47,48,49,50,52,53, 54,55,57,58,59,62, 63.

Appendix 1a Continued.

Voucher No.	Scientific name (Family name CAPITALIZED)	Stand No.
4858	Schefflera volkensii (Harms) Harms. (ARILACEAE)	54,55,56,57,58,59, 60,61,62,64,65,66, 67,68,69,70,71,72, 73,74.
91	Scutia myrtina (Burm.f.) kutz (RHAMNACEAE)	1,2.
93	Senecio gigas Vatke (ASTERACEAE)	31,32,36,37,39,50, 52,53,56,59,66,67, 68.
98	Strychnos mitis S.Moore (LOGANIACEAE)	4,5,6,7,8,9,10,11, 12,13,14,15,16,17, 18,19.
99	Suregada procera (Prain) Croizat. (EUPHORBIACEAE)	4,5,6,7,9,10,12, 13,14,15,16,17,18, 19,20,21,22.
101	Syzygium guineense (Willd.) Dc. (MYRTACEAE)	3,5,7,8,9,12,13,14, 15,16,17,18,19,20, 21,22,23,24,25,26, 27,28,29,30,31,32, 33,34,35,36,37,38, 39,40,41,42,43,44, 45,46,48.
102	Syzygium guineense (Willd.)Dc.var macrocarpum (MYRTACEAE)	1.
103	Teclea nobilis Del. (RUTACEAE)	5,6,7,12,15,16,17, 20,26,27,28,29,30, 31,32,33,34,35,36, 37,38,39,40,41,42, 43,44,45,46,47,48, 49,50,51,52,53,54.

Appendix 1a Continued.

Voucher No.	Scientific name (Family name CAPITALIZED)	Stand No.
104	Teclea simplicifolia (fee) Alston (RUTACEAE)	2,3,4,6,7,8,9,10,12, 13,15,16,17,18,19,22, 26,30,31,34,.
109	Trema orientalis (ULMACEAE)	2,5,16,18,19,20,21, 22.
111	Turrae holstii Gurke (MELIACEAE)	13,16,19,20,21,22, 25,27,28,29,30,31, 32,37.
112	Vepris dainelli (Pichi-Serm.) Kokwaro (RUTACEAE)	2,3,4,6,7,8,9,11, 16,20,23,24,25,26, 27,28,29,31,33,34, 36,37,38,39,40,41, 43,44,45,46,47,49, 50,51,53,
5149	Vernonia amygdalina Del. (ASTERACEAE)	20,21,22,25,32,34, 35,42,43,45,48,52, 56,58,60.
4955	Vernonia auriculifera Hiern (ASTERACEAE)	20,21,22,25,33,34, 41,42,43,
5580	Vernonia hymenolepis A. Rich. (ASTERACEAE)	18,20,24,25,26,28, 30,33,35,37,38,40, 41,44,47,49,54,56, 57.
4	Warbugia ugandensis Sprague (CANELLACEAE)	4,5,7,8,10,11,12, 13,14,15,16,18,19, 20,21,22,23,25,26, 27,28.

-- Voucher specimen not collected

* Possibly a new taxon.

Appendix 1b.

Vegetation Data Collected from the Harenna Forest

II. Herbs, Epiphytes, and Lianes

Voucher No.	Scientific name (Family name CAPITALIZED)	Stand No.
1	Acalypha psilostachys Hochst (EUPHORBIACEAE)	1,2,3
4986	Acanthopale sp. aff.A. laxiflora (ACANTHACEAE)	16,18,20,22,23,25, 26,29,33,34,35,36, 37,38,41,43,44,45, 46,47.
2	Acanthus eminens C.B.cl. (ACANTHACEAE)	23,24,25,26,27,29, 31,34,35,36,39,40, 41,42,44,45,46,47, 48,49,50,51,52,53, 55,57,58,68,69,72, 73.
4928	Acanthus sennii Chiov. (ACANTHOCEAE)	52,54,57,60,61,62, 70,71,72,73.
5478	Agrocharis melanantha Hochst. (APIACEAE)	64,65,66,68,69,70, 71,72,73,74.
5442	Alchemilla haumanii Roth (ROSACEAE)	74,75
5470	Anthemis tigreensis J. Gray ex. Rich (ASTERACEAE)	74,75.
5372	Anthoxanthum aethiopicum I. Hedb. (POACEAE)	55,56,57,58,59,60, 61.
5449	Artemisia afra Jaq. ex. Willd (ASTERACEAE)	75.
11	Asparagus africanus Lam (LILIACEAE)	61,62,65,69,70,71.
5316	Asplenium abyssinicum Fee (ASPLENIACEAE)	43,44,45,46,47,48, 49,50,51,52,53,54.

Voucher No.	Scientific name (Family name CAPITALIZED)	Stand No.
5347	Asplenium sp. aff. aethiopicum (Burm.f.) Becherer. (ASPLENIACEAE)	25,37,41,43,52,54, 56,58,60,61,64,
4834	Asplenium anisophyllum Kze (ASPLENIACEAE)	40,41,45,46,47,48, 49,51,52,53,54.
12	Asplenium manii Hook (ASPLENIACEAE)	7,8,9,11,13,15,16,18, 21,24,26,28,29,32,33, 63,64,65,66,67.
3	Asystasia gangetica (L.) T. Anders (ACANTHACEAE)	9,11,12,13,15,16,17, 21,22,24,26,27,28,29, 31,38,59,60,61,62.
--	Australina caffra (Thumb) Fourc. (URTICACEAE)	23,26,31,32,33,35,36.
5310	Bassella alba L. (BASELLACEAE)	49,50,51,53,54,58,59.
15	Bulbophyllum josephii (O.Ktze.) Summerch. (ORCHIDACEAE)	35,36,37,38,39.
11	Caesalpinia volkensii Harms. (CAESALPINIACEAE)	3,6,9,13,18,19,23,25, 27,29.
4838	Canarina eminii Schweinf. (CAMPANULACEAE)	56,57,58,59,60,61,62, 63,64,65,66,67,68,69, 71.
5340	Cardamine obliqua A. Rich (BRASSICACEAE)	71,72,73.
5357	Cerastium afromontanum T.C.E. Fr. & Weimark. (CARYOPHYLLACEAE)	41,43,46,47,49,58,59, 60,61,62,67.
22	Chlorophytum sparsiflorum Baker (LILIACEAE)	7,9,17.
5305	Clematis simensis Fresen (RANUNCULACEAE)	61,62,64,65,67,68,70, 71,72.
24	Clutia abyssinica Jaub & Spach (EUPHORBIACEAE)	1,2,3,10,13,21,24.
5358	Coccinia grandis Cogn. (CUCURBITACEAE)	61,62,63,64,66,67,69, 72.
29	Commelina africana L (COMMELINACEAE)	1.

Appendix 1b continued

Voucher No.	Scientific name (Family name CAPITALIZED)	Stand No.
5462	Conyza abyssinica Sch. Bip.ex. Oliv & Hiern (ASTERACEAE)	15,18,19,20,23,25,27, 28,29,30.
32	Cucumis sp.(CUCURBITACEAE)	27,29,30,32,33,36.
5326	Cynoglosum geometricum Bak. & Wright. (BORAGINACEAE)	56,57,58,60,61,62,63, 64,65,66,68,70,71,72, 73.
33	Dalbergia lactea Vatke (LEGUMINOSEAE)	19,21,22,23,25.
34	Desmodium repandum (Vahl.) Dc. (LEGUMINOSAE) 30,31.	3,4,5,6,7,8,10,13,14, 18,19,20,21,22,28,29,
5321	Diaphananthe adoxa Rasm. (ORICHIDACEAE)	41,43,45,46,47,48,49, 50,51,52,54,55,57,58, 60.
5448	Dichrocephala chrysanthemifolia (ASTERACEAE)	62,63,67,68,69,70,71, 74,75.
119	Dryopteris concolor (Langsd. & Fisch.) Kuhn. (SINOPTERIDACEAE)	4,5,6,7,14,27,33,36, 37,39,
5601	Drougetia iners (Forssk.) Schweinf (URTICACEAE)	17,23,24,31,36,37,38, 41,42,44,47,49,50,54, 55.
37	Drynaria volkensii Hieron (POLYPODIACEAE)	6,14,17,18,20,21,22, 22,23,24,25,26,27,28, 29,30,31,32,33,34,35, 36,37,38,39,45,47,49, 50.
4819	Dryopteris inaequalis (Schlechtend.) Kuntze (ASPIDIACEAE)	40,41,42,44,45,47,48, 49,53,54,57,58,61
39	Elatostema monticolum Hook.f. (URTICACEAE)	32,42,44.

Appendix 1b continued.

Voucher No.	Scientific name (Family name CAPITALIZED)	Stand No.
5323	Embelia schimperi Vatke. (MYRSINACEAE)	54,55,56,57,62,65,68, 69.
5464	Epilobium stereophyllum Fresen (ONAGRACEAE)	73,74.
4865	Galium aparinoides Forssk (RUBIACEAE)	55,57,63,64,67,68,71.
5453	Galium simensis Fresen (RUBIACEAE)	63,64,65,67,70,71, 75.
4821	Galium spurium L (RUBIACEAE)	43,47,52,53,54.
5339	Galium thunbergianum Ekl. & Zeyl. (RUBIACEAE)	63,64,67,68,69,71,72.
47	Geophila repens (L.) Johnston (RUBIACEAE)	8,9,10,12,13,15,16,17.
5469	Geranium aculeolatum Oliv (GERANIACEAE)	72,73,74,75.
5025	Giradinia bullosa (Steud.) Weddel. (URTICACEAE)	57,58,59,61.
--	Giradinia diversifolia (Link.)Friis. (URTICACEAE)	57,59,60,61,62.
5023	Gouania longispicata Engl. (RHAMNACEAE)	2,5,9,15,16,22,24,25, 27,29,30,31,33.
5471	Hebenstretia dentata L. (SCROPHULARIACEAE)	70,71,72,73,74,75.
5341	Helichrysum citrispinum Del.(ATERACEAE)	63,64,66,69,70,71,72, 73,74,75.
5459	Helichrysum cymosum (L.) Less.(ASTERACEAE)	75.
48	Helichrysum formosissimum A. Rich.(ASTERACEAE)	75.
5450	Helichrysum odoratissimum ((L.) Less (ASTERACEAE)	75.
5451	Helichrysum splendidum (Thunb.)Less (ASTERACEAE)	75.

Appendix 1b continued.

Voucher No.	Scientific name (Family name CAPITALIZED)	Stand
49	Hippocratea africana (Willd. Loes. (CELASTRACEAE)	5,7,8,9,10,12,14, 18.
51	Hypoestes aristata (Vahl.) Roem. (ACANTHACEAE)	4,8,14,17,26,28,30, 32,33,34,37,38,39, 42,43,45,48,49,50, 51,57,58,59,60.
5308	Impatiens aethiopica Grey-Wilson. (BALSAMINACEAE)	51,52,53,54,55,56, 57,59,60,61,62,63, 66,68,69,70.
52	Impatiens rothii Hook. F. (BALSAMINACEAE)	44,45,49,52,54,57, 63,64,65,66,67,70, 71,72,74.
53	Indigofera colutea (Burm. f.)Merr. (LEGUMINOSAE)	1.
4887	Isoglossa punctata (Vehl.) Brummitt ex. Wood. (ACANTHACEAE)	17,18,21,22,23,25, 27,30,34,35,36,38, 39.
54	Isoglossa somalensis Lindau (ACANTHACEAE)	21,23,25,26,27,31, 32,33,35,36,39,42, 43,44,45,46.
55	Jasminum abyssinicum Dc. (OLEACEAE)	29,30,32,33,37,38, 39,40,41,42,43,44, 46,47,48,49,50,51, 52,53,54,56,58,59, 62,67,69.
56	Jasminum grandiflorum L. sub. sp. floribundum (R.Br. ex. Fresen)P.S.Green (OLEACEAE)	3,4,5,6,8,11,12,13, 14,15,16,17,18,20, 21,23,28,40,442,44, 45.
5344	Kniphofia foliosa Hochst (LILIACEAE)	62,63,64,65,68,70,71, 72,74.

Appendix 1b continued.

Voucher No.	Scientific name (Family name CAPITALIZED)	Stand No.
5474	Liparis abyssinica Rich. (ORCHIDACEAE)	40,42,43,44,46,47,55, 58.
61	Lobelia scebelii Chiov (CAMPANULACEAE)	51,52,55,56,58,60,61, 64,65,66,67,68,69,70, 71,72,73,74.
62	Lotus discolor E.Mey (LEGUMINOSAE)	71,72,73,74,75.
121	Loxogramme lanceolata (Sw.)Pr.(POLYPODIACEAE)	7,8,9,10,11,13,14,15, 18,21,23,25,29,30,33, 38,41,42,43,44,45,48, 52.
5320	Lycopodium dacryioides Baker.(LYCOPODIACEAE)	56,57,58,60,63.
68	Mimulopsis solmsii Schweinf (ACANTHACEAE)	39,41,42.
5045	Oncoba routledgei Sprague (FLACOURTIACEAE)	35,36,38,39,40,41,42, 43,44,45,
5570	Oplismenus compositus (L.) P.Beauv. (POACEAE)	4,5,6,7,8,9,10,11,12, 14,17,19,20,21,22,25, 26,29,31,33,34,35,37, 38,39,42,43,44,48,51, 55,56.
74	Paederia pospischilii K. Schum. (RUBIACEAE)	1,2.
5614	Panicum monticolum Hook.F. (POACEAE)	1,2,3,4,5,6,7,8,10,11, 12,13,14,15,17,18.
75	Pavonia urens Cav. (MALVACEAE)	23,30,31,32,58.
5070	Pentas lanceolata (Forssk.) Deflers. (RUBIACEAE)	17,20,24,25,26,30,31, 32,33,34,35.
76	Peperomia retusa (L.F.)A. Dietr. (PEPEROMIACEAE)	30,32,34,37,38,39.
77	Peponium vogelii (Hook.f.) Engl. (CUCURBITACEAE)	30,32,34,36,37,38, 39,40.

Appendix 1b continued.

Voucher No.	Scientific name (Family name CAPITALIZED)	Stand No.
78	Phyllanthus ovalifolius (EUPHORBIACEAE)	17,18,19.
5317	Pilea johnstonii Oliv. (URTICACEAE)	42,44,46,47,48,49, 51,52,53,54,55,56, 62,69.
5467	Pimpinella oreophila Hook. f. (APIACEAE)	43,63,64,65,66,68, 69,70,71,73,74.
79	Plectranthus (Isodon) Schimperi Vatke. (LAMIACEAE)	21,26,27,29,31,38, 39,40,41,44,46.
5332	Polystichum setiferum (Forssk) Moore.ex. Woyner Var.fuscopaleaceum (Alston) Schelpe. (ASPIDIACEAE)	56,57,60,61,62,63, 65,66,72.
5324	Pseudocardumeminii H. Wolff. (APIACEAE)	54,55,63,64,65,66, 67,68,69,72,73.
120	Pterolobium stellatum (Forssk.) Brenan. (LEGUMINOSAE)	2,2,2,1,2,1.
83	Pupalia lappacea (L.)Juss. (AMARANTHACEAE)	3,7,14,18,20,22,24, 25,26.
5476	Ranunculus oreophytus Delile (RANUNCULACEAE)	73,74.
5348	Salvia merjamie Forssk (LAMIACEAE)	63,64,65,66,67,71.
89	Sanicula elata Buch.-Ham. ex.D.Don.(APIACEAE)	18,19,20,26,27,34, 39,40,42,44,52,53, 55,57,60,61,62,63, 64,65.66.
5356	Satureja paradoxa (Vatake) Engl. (LAMIACEAE)	61,62,63,64,65,67, 71,73.
5331	Satureja simensis (Benth.) Briq (LAMIACEAE)	63,65,66,73,74.
5465	Scabiosa columberia L. (DIPBACACEAE)	71,72,73,74.

Appendix 1b continued.

Voucher No.	Scientific name (Family name (CAPITALIZED)	Stand No.
90	Scadoxus nutans (Friis & Bjornst.) Friis & Nordal. (AMARYLLIDACEAE)	32,33,34.
--	Schefflera myriantha (Bak.)Drake. (ARALIACEAE)	17,19,23,25,28,29,34, 36,38,40,41.
5354	Selaginella kraussiana (Kze.)A. Br. (SELAGINELLACEAE)	40,55,57,59,60,61,62, 64.
5456	Senecio ochrocarpoides Cuf. (ASTERACEAE)	62,64,67,69,70,71.
94	Solanum benderianum Dammer (SOLANANCEAE)	58,59,60.
95	Solanum giganteum Jaq. (SOLANACEAE)	19,21,22,23.
96	Solanum indicum L. (SOLANACEAE)	55,56,58,59.
116	Stachys aculeolata Hook F. (LAMIACEAE)	23,26,31,33.
97	Stephania abyssinica (Dill. & Rich)Walp (MENISPERMACEAE)	37,38,39,40,41,42,43, 44,46,50,51,52,55,56, 57,58,59,61,62,63.
100	Swertia sp.(GENTIANACEAE)	73,74,75.
105	Tectaria gemmifera (Fee) Alston.(ASPIDIACEAE)	5,6,11,13,14,15,16, 17,18.
106	Thalictrum rhynocarpum Dill. & A.Rich (RANUNCULACEAE)	18,23,24,28,39,40,51, 56,57.
107	Toddalia asiatica Lam (RUTACEAE)	3,6,13,16.
108	Tragia brevipes Pax. (EUPHORBIACEAE)	12,14,15.

Appendix 1b continued.

Voucher No.	Scientific name (Family name CAPITALIZED)	Stand No.
5452	Trifolium burchellianum Ser. (LEGUMINOSAE)	70,71,74,75.
110	Trifolium semipilosum Fresen.(LEGUMINOSAE)	66.67,68,70,71,72,73.
4851	Uebelinia kiwuensia Th.C. E.Fries. ssp. kiwuensis. (CARYOPHYLIACEAE)	56,57,58,59,60,62,68, 69,70,71,72.
5343	Umbilicus botryoides A. Rich. (CRASSULACEAE)	59,60,63,65,68,69,70, 72,73.
113	Urera hypselodendron (A. Rich.) Weddel.(URTICACEAE)	28,29,31,33,34,35, 36,37,39,40,41,42, 43,44,45,46,47,48, 49,50,51,52,53,56, 57,58,59,61,62.
--	Ismea sp.	59,60,61,63,64,65, 66,68,69,70,71,72, 73,74.
114	Verbascum sinaiticum Benth. (SCROPHULARIACEAE)	1.
115	Zehneria scabra (L.f.)Sond. (CUCURBITACEAE)	61,62,63,64,65,66, 67,70,71,72,73,74.

-- Voucher specimen not collected.

Appendix 2a. Fusions of the Similarity matrix in the presence - absence data.

Program GROUPAGE.

Individuals = 75 Attributes = 88

1. WPGMA Fusions of the Similarity Matrix

STEP	GROUPS	FUSED	NEW CODE	ON LEVEL
1	67	64	76	.8462
2	74	73	77	.8333
3	28	27	78	.8214
4	70	69	79	.8000
5	48	45	80	.7727
6	47	46	81	.7727
7	78	29	82	.7417
8	57	55	83	.7273
9	43	41	84	.7273
10	37	36	85	.7143
11	51	49	68	.7083
12	79	72	87	.7071
13	59	58	88	.6957
14	76	68	89	.6923
15	9	8	90	.6897
16	80	44	91	.6897
17	77	71	92	.6875
18	81	91	93	.6829
19	61	60	94	.6667
20	53	50	95	.6667
21	89	66	96	.6548
22	42	35	97	.6538
23	87	92	98	.6533
24	32	31	99	.6452
25	90	10	100	.6351
26	83	88	101	.6209
27	34	33	102	.6207
28	14	12	103	.6207
29	84	93	104	.6092
30	86	95	105	.6067
31	19	18	106	.6061
32	15	5	107	.6000
33	100	6	108	.5864
34	22	21	109	.5862
35	98	65	110	.5838
36	104	40	111	.5778
37	97	38	112	.5725
38	85	102	113	.5718
39	105	52	114	.5646
40	99	30	115	.5636
41	108	7	116	.5631
42	111	112	117	.5487
43	101	54	118	.5454

Appendix 2a. Continued

STEP	GROUPS	FUSED	NEW CODE	ON LEVEL
44	109	20	119	.5388
45	82	115	120	.5384
46	24	23	121	.5333
47	3	2	122	.5185
48	116	4	123	.5178
49	94	62	124	.5125
50	106	16	125	.5067
51	117	39	126	.5047
52	123	11	127	.5009
53	118	56	128	.4960
54	120	26	129	.4924
55	96	110	130	.4907
56	103	13	131	.4834
57	107	127	132	.4804
58	121	25	133	.4747
59	131	17	134	.4703
60	113	126	135	.4615
61	129	133	136	.4466
62	132	134	137	.4461
63	119	125	138	.4349
64	114	128	139	.4317
65	137	138	140	.3879
66	124	139	141	.3354
67	135	136	142	.3193
68	122	140	143	.2965
69	130	63	144	.2818
70	142	143	145	.2065
71	141	144	146	.1844
72	146	75	147	.9999E-01
73	145	1	148	.7135E-01
74	147	148	149	.5656E-01

Appendix 2b. Fusions of the Similarity matrix in the quantative data

PROGRAM GROUPAGE

Individuals = 75 Attributes = 118

1. WPGMA Fusions of the Similarity Matrix

STEP	GROUPS	FUSED	NEW CODE	ON LEVEL
1	71	70	76	.6250
2	50	49	77	.6190
3	69	68	78	.6118
4	36	35	79	.6078
5	65	64	80	.6040
6	80	66	81	.5879
7	81	63	82	.5653
8	38	37	83	.5600
9	73	72	84	.5577
10	61	60	85	.5575
11	22	21	86	.5556
12	14	4	87	.5484
13	16	15	88	.5439
14	10	8	89	.5333
15	44	42	90	.5213
16	87	6	91	.5180
17	31	26	92	.5125
18	47	46	93	.5082
19	89	7	94	.4891
20	13	11	95	.4889
21	39	34	96	.4881
22	85	57	97	.4726
23	77	48	98	.4623
24	33	32	99	.4595
25	76	84	100	.4564
26	88	95	101	4460
27	2	1	102	.444
28	83	96	103	.4317
29	98	53	104	.4212
30	100	74	105	.4154
31	91	5	106	.4144
32	29	25	107	.4103
33	97	62	108	.4055
34	101	9	109	.4036
35	52	51	110	.3919
36	59	58	111	.3854
37	20	18	112	.3824
38	45	43	113	.3718
39	104	110	114	.3643
40	93	41	115	.3562
41	94	106	116	.3559
42	78	82	117	.3540
43	107	27	118	.3500

Appendix 2b. continued

STEP	GROUPS	FUSED	NEW CODE	ON LEVEL
44	90	113	119	.3494
45	92	99	120	.3397
46	79	23	121	.3385
47	114	54	122	.3266
48	108	56	123	.3169
49	109	12	124	.3070
50	118	121	125	.3006
51	106	117	126	.2998
52	111	123	127	.2822
53	116	3	128	.2802
54	115	119	129	.2782
55	112	28	130	.2746
56	124	17	131	.2720
57	86	19	132	.2687
58	103	120	133	.2620
59	133	30	134	.2445
60	122	55	135	.2393
61	128	130	136	.2237
62	126	67	137	.2235
63	125	134	138	.2066
64	129	135	139	.1948
65	132	136	140	.1930
66	131	140	141	.1728
67	139	40	142	.1707
68	138	24	143	.1656
69	141	143	144	.1392
70	127	142	145	.1387
71	137	75	146	.9265E-01
72	102	144	147	.6844E-01
73	145	146	148	.4093E-01
74	147	148	149	.1357E-01

Appendix 3a. Species Richness in the presence - absence data

PROGRAM CHECK

Individuals = 75 Attributes = 88

SPECIES RICHNESS

The figures in parenthesis are stand codes

(1)	**	12
(2)	**	24
(3)	**	17
(4)	**	24
(5)	**	24
(6)	**	23
(7)	**	24
(8)	**	24
(9)	**	25
(10)	**	27
(11)	**	25
(12)	**	23
(13)	**	18
(14)	**	24
(15)	**	24
(16)	**	27
(17)	**	23
(18)	**	28
(19)	**	25
(20)	**	27
(21)	**	23
(22)	**	23
(23)	**	21
(24)	**	25
(25)	**	22
(26)	**	28
(27)	**	27
(28)	**	24
(29)	**	25
(30)	**	26
(31)	**	24
(32)	**	27
(33)	**	23
(34)	**	24
(35)	**	22
(36)	**	24
(37)	**	24
(38)	**	17
(39)	**	17
(40)	**	19
(41)	**	20
(42)	**	21
(43)	**	18

Appendix 3a continued

(44)	**	21
(45)	**	18
(46)	**	19
(47)	**	20
(48)	**	21
(49)	**	21
(50)	**	20
(51)	**	20
(52)	**	20
(53)	**	20
(54)	**	19
(55)	**	19
(56)	**	19
(57)	**	19
(58)	**	18
(59)	**	21
(60)	**	16
(61)	**	14
(62)	**	12
(63)	**	6
(64)	**	11
(65)	**	7
(66)	**	13
(67)	**	13
(68)	**	10
(69)	**	10
(70)	**	8
(71)	**	8
(72)	**	8
(73)	**	5
(74)	**	6
(75)	**	2

Appendix 3b. Species Richness in the quantitative data

PROGRAM CHECK

Individuals = 75 Attributes = 118

SPECIES RICHNESS

The figures in parenthesis are stand codes

(1)	**	8
(2)	**	6
(3)	**	9
(4)	**	7
(5)	**	9
(6)	**	10
(7)	**	10
(8)	**	10
(9)	**	10
(10)	**	9
(11)	**	8
(12)	**	8
(13)	**	11
(14)	**	13
(15)	**	12
(16)	**	9
(17)	**	15
(18)	**	17
(19)	**	10
(20)	**	9
(21)	**	14
(22)	**	10
(23)	**	17
(24)	**	10
(25)	**	16
(26)	**	15
(27)	**	11
(28)	**	12
(29)	**	16
(30)	**	14
(31)	**	15
(32)	**	13
(33)	**	17
(34)	**	16
(35)	**	11
(36)	**	15
(37)	**	13
(38)	**	18
(39)	**	18
(40)	**	16
(41)	**	18
(42)	**	18
(43)	**	15

Appendix 3b continued

(44)	**	19
(45)	**	15
(46)	**	13
(47)	**	14
(48)	**	11
(49)	**	13
(50)	**	10
(51)	**	14
(52)	**	16
(53)	**	12
(54)	**	15
(55)	**	16
(56)	**	17
(57)	**	23
(58)	**	22
(59)	**	18
(60)	**	21
(61)	**	24
(62)	**	25
(63)	**	25
(64)	**	23
(65)	**	21
(66)	**	19
(67)	**	17
(68)	**	19
(69)	**	20
(70)	**	20
(71)	**	27
(72)	**	23
(73)	**	23
(74)	**	20
(75)	**	15

Appendix 4

Altitude, Slope and Aspect of the Stands from the Harenna Forest

Stand No.	Altitude (meters)	Slope (°)	Aspect
1	1500	4	NE
2	1500	3	NW
3	1510	3	NW
4	1490	1	NW
5	1500	1	NW
6	1540	4	NW
7	1540	5	NW
8	1525	6	NW
9	1530	4	NW
10	1530	4	NW
11	1545	4	NE
12	1520	6	NW
13	1510	8	NW
14	1515	10	NW
15	1520	4	NE
16	1565	2	NE
17	1580	4	NW
18	1600	5	NW
19	1600	5	NW
20	1600	5	NE
21	1640	1	SW
22	1660	9	SW

Appendix 4 continued.

Stand No.	Altitude (meters)	Slope (°)	Aspect
23	1670	8	SW
24	1700	2	NE
25	1700	4	SW
26	1700	6	SE
27	1750	8	SW
28	1750	4	NW
29	1770	2	NW
30	1800	4	SW
31	1810	5	NE
32	1830	6	E
33	1840	3	NW
34	1880	2	SW
35	1900	4	SE
36	1900	5	SE
37	1930	5	NE
38	1950	3	SE
39	1980	4	SE
40	1925	19	N
41	1930	6	SW
42	1980	12	SW
43	2030	5	NE
44	2040	1	NW

Appendix 4 continued

Stand No	Altitude (meters)	Slope (°)	Aspect
45	2050	8	NE
46	2070	15	SW
47	2115	20	W
48	2130	4	N
49	2160	4	NE
50	2260	5	NE
51	2260	15	NE
52	2300	12	NE
53	2350	23	N
54	2380	25	NE
55	2390	14	NW
56	2420	4	N
57	2470	25	NW
58	2530	12	NE
59	2590	18	E
60	2670	22	N
61	2780	15	NE
62	2800	11	N
63	2810	9	NE
64	2830	11	N
65	2850	12	SE
66	2870	17	N

Appendix 4 continued

Stand No.	Altitude (meters)	Slope (°)	Aspect
67	2900	5	NE
68	2910	15	N
69	2930	22	NE
70	3040	11	NE
71	3100	12	NW
72	3140	8	NE
73	3200	22	SE
74	3200	30	SE
75	3300	11	NW

N = North

NE = North East

E = East

SW = South West

S = South

W = West

NW = North West

Appendix 5

Soil Data Collected from the Harenna Forest

Stand No.	% Sand		% Clay		% Silt		% O.M.	
	TS	SS	TS	SS	TS	SS	TS	SS
3	20.2	18.2	75.2	76.9	4.6	4.9	6.0	0.80
4	28.2	22.2	56.5	66.5	15.3	11.3	4.8	2.39
9	30.2	19.3	54.2	71.9	15.6	8.6	6.4	1.8
10	29.5	15.7	57.4	75.8	12.8	8.2	9.2	1.8
17	31.7	9.4	49.8	78.2	18.5	12.4	11.9	2.79
18	27.6	11.3	52.3	76.4	20.2	11.9	7.3	0.8
25	33.7	9.6	44.8	74.4	21.7	16.0	12.0	33.2
26	31.1	13.1	49.2	73.3	19.6	13.6	7.6	2.4
33	38.9	16.8	45.2	69.2	15.9	14.0	9.8	3.4
34	38.9	18.2	41.2	70.5	19.9	10.7	9.6	3.2
41	38.8	19.8	40.6	65.3	20.7	41.9	9.6	3.4
42	49.8	17.5	35.9	68.7	14.3	13.7	11.2	3.6
49	41.6	21.6	56.2	60.5	2.3	18.0	9.9	2.5
50	43.6	25.4	38.0	58.9	18.4	15.7	11.3	2.5
57	43.5	25.0	41.0	60.9	15.2	14.0	8.6	3.5
58	43.1	24.1	38.9	58.9	17.9	17.0	6.8	4.1
65	52.7	33.0	32.8	38.6	14.7	28.4	10.0	6.8
66	34.9	21.0	48.2	64.2	17.1	14.9	10.0	2.8
73	29.0	19.0	45.8	63.9	25.2	17.1	8.8	2.3
74	29.1	19.4	25.9	61.6	45.0	19.1	9.4	1.5

Appendix 5 continued

Stand No.	% Sand		% Clay		% Silt		% O.M.	
	TS	SS	TS	SS	TS	SS	TS	SS
81	41.3	30.0	29.4	39.4	29.2	30.7	11.9	4.6
82	41.9	37.8	21.4	23.5	36.7	38.7	13.5	1.4
89	29.8	17.6	39.8	63.8	30.4	18.6	9.3	2.6
90	23.6	19.6	59.9	61.9	16.5	18.5	9.1	3.6
97	36.6	27.8	34.9	52.5	29.4	19.7	8.4	3.9
98	30.4	24.1	30.1	56.0	39.5	20.0	5.6	4.8
105	32.0	22.0	20.0	36.5	45.1	41.6	13.8	6.8
106	29.8	23.4	28.7	34.7	41.4	42	11.6	6.6
113	28.6	22.3	32.6	46.6	39.0	30.9	10.4	1.52
114	28.3	24.2	30.5	38.2	41.3	37.6	10.4	6.9
121	26.2	22.0	16.2	21.9	57.2	56.1	15.2	7.0
122	36.3	34.3	20.0	33.7	43.9	41.9	14.0	6.9
129	34.7	28.7	23.3	26.8	42.0	49.5	14.6	6.8
130	32.7	28.7	21.1	25.3	46.0	46.0	10.6	6.8
137	32.1	24.0	35.9	46.0	32.0	30.0	8.4	5.0
138	31.6	23.6	31.5	42.5	36.9	34.0	9.6	2.6
145	31.6	21.3	30.6	48.7	37.8	30.4	10.9	6.8
146	31.4	24.7	38.2	46.2	30.4	29.1	12.7	5.6
149	40.7	34.8	12.2	14.9	47.1	50.4	18.8	6.8
150	44.5	34.4	10.9	18.3	44.6	47.3	13.3	6.6

TS = Top soil; SS = Sub soil; O.M.= Organic matter.

Appendix 5 continued

Stand No.	PH in KCl		Conductivity in mmhos/cm		Soil colour Hue(YR) Value chroma	
	TS	SS	TS	SS	TS	SS
3	5.3	4.00	0.37	0.12	5YR/	2.5 YR3/6
4	4.9	4.1	0.52	0.11	5YR $\frac{3}{3}$	2.5 YR $\frac{3}{6}$
9	5.9	5.8	0.86	0.21	7.5YR $\frac{3}{2}$	5YR $\frac{3}{6}$
10	6.6	5.9	0.58	0.23	7.5YR $\frac{3}{2}$	5YR $\frac{3}{2}$
17	5.5	4.9	0.69	0.26	7.5YR $\frac{3}{2}$	5YR $\frac{3}{4}$
18	5.4	3.7	0.45	0.16	5YR $\frac{3}{4}$	5YR $\frac{3}{3}$
25	6.3	5.9	0.93	0.40	5YR $\frac{3}{4}$	2.5YR $\frac{3}{6}$
26	5.7	5.5	0.69	0.35	5YR $\frac{3}{3}$	5YR $\frac{3}{6}$
33	5.7	4.5	0.52	0.35	5YR $\frac{3}{3}$	2.5YR $\frac{3}{2}$
34	5.8	5.0	0.41	0.35	7.5YR $\frac{3}{2}$	5YR $\frac{3}{3}$
41	7.4	5.7	0.68	0.21	2.5YR $\frac{3}{2}$	5YR $\frac{3}{6}$
42	6.5	6.1	0.41	0.29	5YR $\frac{3}{2}$	5YR $\frac{3}{3}$
49	5.2	3.9	0.20	0.16	5YR $\frac{2}{2}$	5YR $\frac{3}{2}$
50	5.2	4.2	0.64	0.24	5YR $\frac{3}{3}$	5YR $\frac{3}{2}$
57	5.1	3.9	0.64	0.17	5YR $\frac{2}{2}$	5YR $\frac{3}{2}$
58	4.7	4.3	0.87	0.24	5YR $\frac{2}{2}$	5YR $\frac{3}{2}$

Appendix 5 continued

Stand No.	PH in KCl		Conductivity in mmhos/cm		Soil Colour Hue(YR) Value/Chroma	
	TS	SS	TS	SS	TS	SS
65	5.9	5.6	0.21	0.35	5YR 3/2	5YR 3/2
66	5.8	5.4	0.41	0.21	5YR 2/2	2.5YR 2/4
73	5.6	4.9	0.87	0.11	5YR 2/2	5YR 3/2
74	5.4	4.8	0.98	0.16	7.5YR 3/2	7.5YR 3/2
81	5.2	4.0	0.35	0.04	5YR 2/2	5YR 2/2
82	5.4	4.7	0.26	0.06	5YR 2/2	5YR 2/2
89	5.0	4.4	0.52	0.13	5YR 2/2	5YR 2/2
90	5.1	3.7	0.35	0.35	5YR 2/2	5YR 2/2
97	5.5	5.1	0.87	0.06	5YR 2/2	5YR 3/2
98	5.1	4.5	0.28	0.08	5YR 3/2	5YR 3/2
105	4.4	4.3	0.06	0.06	5YR 3/2	5YR 3/2
106	4.2	4.3	0.25	0.58	5YR 3/2	5YR 3/2
113	3.9	4.0	0.64	0.16	5YR 3/2	5YR 3/3
114	4.0	4.0	0.70	0.18	5YR 3/3	5YR 3/2

Appendix 5 continued.

Stand No.	PH in KCl		Conductivity in mmhos/cm		Soil Colour Hue(YR) Value/Chroma	
	TS	SS	TS	SS	TS	SS
121	4.1	4.2	0.52	0.08	5YR3/2	5YR3/2
122	4.2	4.5	0.09	0.09	5YR3/2	5YR3/2
129	4.5	4.6	0.35	0.09	5YR3/2	5YR3/2
130	4.8	4.2	0.06	0.13	5YR3/2	5YR3/2
137	3.8	3.8	0.35	0.35	5YR3/2	5YR3/2
138	4.3	3.9	0.41	0.06	5YR3/2	5YR3/2
145	4.5	3.9	0.54	0.12	5YR4/4	5YR4/4
146	4.7	3.9	0.52	0.09	5YR4/4	5YR4/4
149	4.3	4.2	0.06	0.07	5YR2/2	5YR2/2
150	4.2	4.3	0.17	0.06	5YR2/2	5YR3/2

Appendix 5 continued

Stand No.	Exchangeable cations in meq/100g. soil							
	Ca		Mg		K		Na	
3	22.8	3.3	5.1	3.3	0.33	0.06	0.42	0.28
4	13.3	6.6	5.3	3.5	0.43	0.09	0.24	0.27
9	27.8	13.2	5.1	4.7	0.47	0.15	0.30	0.21
10	35.0	16.6	5.9	3.7	0.98	0.21	0.35	0.21
17	28.5	10.0	4.9	4.7	0.53	0.13	0.28	0.19
18	21.4	1.0	5.9	1.2	0.62	0.08	0.22	0.24
25	37.1	16.6	8.2	5.3	1.54	0.28	0.26	0.26
26	27.1	9.9	5.5	3.5	0.58	0.11	0.23	0.11
33	32.8	16.7	8.6	5.6	0.82	0.15	0.21	0.28
34	32.8	20.0	7.0	4.7	0.55	0.12	0.28	0.25
41	42.0	16.6	11.0	4.5	2.72	1.97	0.40	0.27
42	46.0	24.2	11.7	6.5	0.82	0.97	0.29	0.28
49	24.2	0.0	6.5	0.55	0.38	0.06	0.26	0.24
50	27.1	6.6	7.2	4.1	0.41	0.09	0.38	0.21
57	25.7	6.6	5.7	0.55	0.55	0.15	0.26	0.28
58	22.8	10.0	5.9	2.2	0.36	0.09	0.25	0.32
65	25.8	32.8	6.5	4.5	0.59	0.72	0.34	0.34
66	25.7	10.0	7.6	8.9	2.23	0.70	0.23	0.27
73	27.8	20.0	6.1	3.5	1.17	0.27	0.30	0.34
74	25.7	6.6	10.0	6.1	2.34	0.15	0.28	0.28
81	28.5	0	9.0	6.0	1.05	0.13	0.30	0.30
82	22.8	3.3	8.2	7.1	0.41	0.09	0.30	0.23

Appendix 5 continued.

Stand No.	Exchangeable cations in meq/100g soil							
	Ca		Mg		K		Na	
	TS	SS	TS	SS	TS	SS	TS	SS
89	25.7	16.6	5.8	6.1	0.88	0.76	0.31	0.28
90	3.3	21.4	1.1	5.9	0.13	0.60	0.19	0.23
97	38.5	21.3	11.3	6.3	2.04	0.76	0.28	0.28
98	28.6	16.6	6.8	5.3	1.71	0.72	0.18	0.19
105	37.8	3.3	6.6	0.53	0.82	0.53	0.28	0.17
106	3.3	19.9	1.1	5.7	0.30	0.62	0.23	0.15
113	0.0	0.0	1.1	0.0	0.81	0.43	0.20	0.17
114	0.0	0.0	0.53	0.0	0.49	0.34	0.17	0.14
121	0.0	0.0	0.53	0.26	0.30	0.26	0.20	0.21
122	3.3	0.0	2.2	4.1	0.64	1.49	0.20	0.24
129	13.2	3.3	2.2	1.1	0.30	0.30	0.28	0.34
130	3.3	3.3	5.7	2.7	0.64	0.86	0.19	0.19
137	1.7	0.0	1.1	0.53	0.90	0.47	0.17	1.66
138	13.3	3.3	3.5	1.6	0.60	0.51	0.18	0.21
145	19.9	0.0	4.5	2.7	0.55	0.47	0.34	0.32
146	20.0	3.3	6.1	1.6	1.81	0.49	0.29	0.27
149	9.9	1.6	2.2	0.53	0.51	0.43	0.2	0.16
150	6.7	13.3	1.1	3.3	0.34	0.26	0.18	0.37

Appendix 6

Comparison of the clusters in presence-absence data by the environmental factors.

6a. Comparison of clusters by altitude and slope (using t-test).

Groups compared	Altitude d.f.	$\bar{X}_1-\bar{X}_2$	t	P	Slope d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A - B	31	-208	-10.47	0.0005	31	-1.0	-1.11	--
C	36	-450	-19.68	0.0005	36	-3.3	-2.26	0.025
D	33	-929	-22.37	0.0005	33	-12.0	-7.36	0.0005
E	33	-1452	-39.88	0.0005	33	-13.0	-8.08	0.0005
B - C	25	-242	-7.88	0.0005	25	-2.3	-1.20	--
D	22	-721	-12.37	0.0005	22	-11.0	-5.05	0.0005
E	22	-1244	-24.51	0.0005	22	-12.0	-5.58	0.0005
C - D	27	-479	-9.14	0.0005	27	-8.7	-3.50	0.001
E	27	-1002	-11.67	0.0005	27	-9.7	-4.01	0.0005
D - E	25	-523	-7.89	0.0005	25	-1.0	-0.37	--

d.f. = Degree of freedom.

$\bar{X}_1-\bar{X}_2$ = The difference between the means of the clusters compared

t = The calculated t-value

P = Probability level of significance

6b.
Comparison of cluster by soil pH (using t-test).

Groups		Top soil				Sub soil		
Compared	d.f.	$\bar{X}_1-\bar{X}_2$	t	P	d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A - B	14	0.87	2.23	0.025	14	1.02	2.37	0.025
C	18	0.5	1.92	0.05	18	0.40	1.14	--
D	18	1.5	5.17	0.0005	18	0.70	2.43	0.025
E	18	1.5	5.56	0.0005	18	1.0	3.13	0.005
B - C	10	-0.37	-1.32	---	10	-0.62	-1.82	---
D	10	0.63	1.70	---	10	-0.32	-1.68	---
E	10	0.63	2.10	0.05	1o	-0.02	-0.13	0.05
C - D	15	1.0	4.60	0.0005	15	0.3	1.18	---
E	15	1.0	2.20	0.025	15	0.6	2.50	0.025
D - E	15	0.2	0.85	---	15	0.3	2.0	0.05

6c. Comparison of clusters by soil conductivity (using t-test)

Groups		Top soil				Sub soil		
Compared	d.f.	$\bar{X}_1-\bar{X}_2$	t	P	d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A - B	14	0.008	0.067	----	14	0.011	0.20	----
C	18	0.101	0.971	----	18	0.082	1.82	0.05
D	18	0.173	1.573	----	18	0.081	1.33	----
E	18	0.283	3.417	0.0025	18	0.122	0.276	----
B - C	10	0.093	0.538	----	10	0.071	1.22	----
D	10	0.173	0.935	----	10	0.070	0.745	----
E	10	0.287	2.142	0.025	10	0.111	1.980	0.05
C - D	15	0.072	0.496	----	15	0.001	0.069	----
E	15	0.186	1.051	----	15	0.004	0.047	----
D - E	15	0.114	0.912	----	15	0.041	0.603	----

6d. Comparison of clusters by soil texture - % of sand (using t-test)

Groups		Top soil				Sub soil		
compared	d.f.	$\bar{X}_1-\bar{X}_2$	t	P	d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A - B	14	-9.8	-2.55	0.025	14	.8.0	-5.93	0.0005
C	18	-2.1	-0.55	----	18	-8.6	-3.64	0.001
D	18	8.2	2.83	0.01	18	-7.0	-4.73	0.0005
E	18	-1.8	-0.60	----	18	-12.0	-7.14	0.0005
B - C	10	7.7	1.58	----	10	-0.60	-0.15	-----
D	10	12.0	6.47	0.0005	10	-1.00	-0.45	----
E	10	8.0	3.18	0.005	10	-4.00	-1.52	
C - D	15	3.70	1.07	----	15	-0.40	-0.13	----
E	15	0.30	0.08	----	15	-3.70	-1.18	----
D - E	15	-4.00	-1.90	0.05	15	-3.00	-1.30	----

6e. Comparison of clusters by soil texture - % of clay (using t-test)

Groups		Top soil				Sub soil		
compared	d.f.	$\bar{X}_1-\bar{X}_2$	t	P	d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A - B	14	6.20	1.08	----	14	12.30	5.62	0.0005
C	18	11.20	2.15	0.025	18	20.20	8.31	0.0005
D	18	23.60	12.36	0.0005	18	33.50	8.72	0.0005
E	18	24.80	5.27	0.0005	18	38.70	9.26	0.0005
B - C	10	5.00	0.69	----	10	7.90	2.26	0.025
D	10	17.40	3.82	0.0025	10	21.20	3.32	0.005
E	10	18.60	3.09	0.01	10	26.40	3.74	0.0025
C - D	15	0.20	0.04	---	15	13.30	2.75	0.01
E	15	5.40	0.10	----	15	18.50	3.54	0.0025
D - E	15	1.2	0.28	----	15	5.2	0.82	----

6f. Comparison of clusters by soil texture - % of silt (using t-test)

Groups		Top soil				Sub soil		
Compared	d.f.	$\bar{X}_1-\bar{X}_2$	t	P	d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A - B	14	3.30	1.05	----	14	-4.3	2.54	0.025
C	18	-9.10	-2.61	0.01	18	-11.6	4.40	0.0005
D	18	-25.60	-9.27	0.0005	18	-24.5	6.67	0.0005
E	18	-23.0	-9.32	0.0005	18	-26.7	9.56	0.0005
E - C	10	-12.70	-2.10	0.05	10	-7.30	-1.55	----
D	10	-29.40	-6.26	0.0005	10	-20.60	-3.13	0.01
E	10	-26.60	-6.46	0.0005	10	22.4	-4.49	0.001
C - D	15	-16.70	-3.70	0.0025	15	-12.90	-2.54	0.025
E	15	13.90	-3.38	0.005	15	-15.10	-3.60	0.0025
D - E	15	2.8	0.87	----	15	-2.2	-0.42	----

6g. Comparison of clusters by organic matter (using t-test)

Groups		Top soil				Sub soil		
Compared	d.f.	$\bar{X}_1-\bar{X}_2$	t	P	d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A - B	14	-0.37	-0.28	----	14	-0.53	-0.33	-----
C	18	-1.41	-1.47	----	18	-0.60	-0.49	----
D	18	-2.39	-1.93	0.05	18	-3.04	-2.39	0.025
E	18	-3.22	-4.03	0.0005	18	-3.36	-2.80	0.005
B - C	10	-1.04	-1.00	-----	10	-0.07	-0.05	----
D	10	-2.02	-1.15	-----	10	-2.51	2.39	0.025
E	10	-2.85	-1.98	0.05	10	-2.83	1.89	0.05
C - D	15	-0.98	-0.80	----	15	-2.44	-2.65	o.01
E	15	-1.11	-1.44	-----	15	-2.76	-3.49	0.001
D - E	15	-0.83	-0.60	----	15	-0.32	-0.38	-----

6h. Comparison of clusters by soil potassium (using t-test)

Groups		Top soil				Sub soil		
Compared	d.f.	$\bar{X}_1-\bar{X}_2$	t	P	d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A - B	14	0.44	1.29	----	14	0.26	0.91	----
C	18	-0.23	-0.70	----	18	-0.06	-0.27	----
D	18	-0.03	-0.10	----	18	-0.28	-1.21	----
E	18	0.16	-0.60	----	18	-0.11	-0.52	----
B - C	10	-0.67	-1.62	----	10	-0.32	-2.06	0.05
D	10	-0.67	-1.42	----	10	-0.54	-2.70	0.025
E	10	-0.28	-1.44	----	10	-0.37	-1.68	----
C - D	15	0.20	0.57	----	15	0.46	2.77	0.01
E	15	0.39	1.23	----	15	0.63	5.25	0.0005
D - E	15	0.19	0.70	----	15	0.17	1.18	-----

6i. Comparison of clusters by soil sodium (using t-test)

Groups		Top soil				Sub soil		
Compared	d.f.	$\bar{X}_1-\bar{X}_2$	t	P	d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A - B	14	0.02	0.43	----	14	-0.03	-0.87	----
C	18	0.01	0.30	----	18	-0.05	-1.76	0.05
D	18	0.07	2.05	----	18	0.03	0.87	----
E	18	0.06	1.36	----	18	-0.02	-0.54	----
B - C	10	-0.01	-0.29	----	10	-0.02	-0.39	----
D	10	0.05	1.62	----	10	0.06	1.27	----
E	10	0.04	0.66	----	10	0.01	0.26	----
C - D	15	0.06	1.88	0.05	15	0.08	2.34	0.025
E	15	0.05	1.16	----	15	0.03	0.62	----
D - E	15	-0.01	-0.22	----	15	-0.05	-1.08	----

6j. Comparison of culsters by soil calcium (using t-test).

Groups		Top soil				Sub soil		
Compared	d.f.	$\bar{X}_1-\bar{X}_2$	t	P	d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A - B	14	5.5	1.18	----	14	7.14	1.85	0.05
C	18	7.4	1.84	0.05	18	-1.0	0.25	----
D	18	16.6	2.77	0.01	18	5.1	1.36	----
E	18	19.5	5.12	0.0005	18	9.3	3.33	0.0025
B - C	10	1.87	0.44	----	10	-8.14	-1.4	----
D	10	11.1	1.22	----	10	-2.04	-0.38	----
E	10	14.0	3.88	0.0025	10	2.2	0.77	----
C - D	15	9.23	1.40	----	15	6.1	1.22	----
E	15	12.13	3.30	0.0025	15	10.3	2.60	0.025
D - E	15	2.9	0.40	----	15	4.2	1.15	----

6k. Comparison of clusters by soil magnesium (using t-test)

Groups		Top soil				Sub soil		
Compared	d.f.	$\bar{X}_1-\bar{X}_2$	t	P	d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A - B	14	0.7	0.57	----	14	2.2	2.68	0.01
C	18	0.3	0.26	----	18	-1.8	2.71	0.01
D	18	3.0	2.12	0.025	18	1.2	1.29	----
E	18	3.7	3.66	0.001	18	2.2	3.88	0.001
B - C	10	-0.4	0.28	----	10	-4.0	-4.03	0.0025
D	10	2.3	1.12	----	10	-1.0	-0.65	----
E	10	3.0	2.92	0.01	10	0.0	0.00	----
C - D	15	2.7	1.64	----	15	3.0	2.73	0.025
E	15	3.4	2.60	0.025	15	4.0	5.88	0.0005
D - E	15	0.7	0.46	----	15	4.1	0.99	----

Appendix 7

Comparison of the clusters in quantitative data by the Environmental factors

7a. Comparison of clusters by altitude and slope (using t-test)

Groups Compared	Altitude d.f.	$\bar{X}_1-\bar{X}_2$	t	P	Slope d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A'-B'	37	-274.38	-11.42	0.0005	37	-1.0	-1.35	----
C'	36	-598.13	-16.74	0.0005	36	-7.75	-4.56	0.0005
D'	27	-2458.57	-68.19	0.0005	27	-11.29	-6.27	0.005
E'	33	-2850	-78.28	0.0005	33	-11.77	-4.23	0.005
B'-C'	31	-323.75	-7.16	0.0005	31	-6.75	-3.63	0.0025
D'	22	-784.15	-15.45	0.0005	22	-10.29	-5.69	0.0005
E'	28	-1175.62	-25.07	0.0005	28	-10.77	-5.67	0.0005
C'-D'	22	-460	-6.72	0.0005	22	-3.54	-1.09	----
E'	27	-851.9	-14.42	0.0005	27	-4.02	-1.44	----
D'-E'	28	-391.43	-6.70	0.0005	28	-0.48	-0.17	----

7b. Comparison of clusters by soil pH (using t-test)

Groups compared	Top soil d.f.	$\bar{X}_1-\bar{X}_2$	t	P	Sub soil d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A'-B'	18	0.55	2.10	0.025	18	0.46	1.30	----
C'	18	0.92	2.20	0.025	18	0.72	2.10	0.025
D'	14	1.86	5.33	0.0005	14	0.94	2.16	0.025
E'	18	1.53	5.91	0.0005	18	1.02	3.26	0.0025
B'-C'	15	0.37	0.86	----	15	0.26	0.96	----
D'	10	1.31	6.23	0.0005	10	0.48	1.41	----
E'	15	0.98	5.76	0.0005	15	0.26	1.08	----
C'-D'	10	0.94	5.88	0.0005	10	0.22	0.96	----
E'	15	0.61	1.45	----	15	0.30	1.67	----
D'-E'	10	-0.33	-1.94	0.05	10	0.08	0.50	----

7c. Comparison of clusters by soil conductivity (using t-test)

Groups compared	Top soil d.f.	$\bar{X}_1-\bar{X}_2$	t	P	Sub soil d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A'-B'	18	-0.007	-0.67	----	18	0.043	1.08	----
C'	18	0.223	2.37	0.025	18	0.075	1.14	----
D'	14	0.113	0.96	----	14	0.117	2.29	0.025
E'	18	0.283	3.37	0.0025	18	0.122	2.77	0.01
B'-C'	15	0.23	1.74	----	15	0.032	0.45	----
D'	10	0.12	3.75	0.0025	10	0.074	2.00	0.05
E'	15	0.29	2.40	0.025	15	0.080	1.98	0.05
C'-D'	10	-0.11	-0.71	----	10	0.042	0.41	----
E'	15	0.06	0.57	----	15	0.047	0.64	----
D'-E'	10	0.17	1.268	----	10	0.005	0.100	----

7d. Comparison of clusters by soil texture - 5% of sand (using t-test)

Groups		Top soil				Sub soil		
compared	d.f.	$\bar{X}_1-\bar{X}_2$	t	P	d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A'-B'	18	6.49	1.83	0.05	18	-7.56	-3.71	0.001
C'	18	0.03	0.01	----	18	-9.28	-4.55	0.0005
D'	14	3.36	0.84	----	14	-9.73	-4.87	0.0005
E'	18	1.74	0.58	----	18	-11.56	-5.78	0.0005
B'-C'	15	6.64	1.90	0.05	15	-1.72	-0.64	----
D'	10	9.85	2.23	0.025	10	-2.17	-0.72	----
E'	15	4.75	1.46	----	15	-4.00	-1.72	----
C'-D'	10	3.21	0.91	----	10	-0.45	-0.12	----
E'	15	1.89	0.70	----	15	-2.28	-0.81	----
D'-E'	10	-5.1	-1.73	----	10	-1.83	-0.56	----

7e. Comparison of clusters by soil texture - % of clay (using t-test)

Groups		Top soil				Sub soil		
compared	d.f.	$\bar{X}_1-\bar{X}_2$	t	P	d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A'-B'	18	9.37	2.06	0.05	18	13.87	4.97	0.0005
C'	18	17.16	3.33	0.0025	18	26.26	5.97	0.0005
D'	14	25.45	4.49	0.0005	14	39.67	10.38	0.0005
E'	18	24.76	5.26	0.0005	18	38.71	9.26	0.0005
B'-C'	15	7.79	1.45	----	15	12.39	2.17	0.25
D'	10	16.11	2.94	0.01	10	25.80	4.43	0.001
E'	15	15.40	3.23	0.0025	15	24.84	4.54	0.0005
C'-D'	10	8.32	1.24	----	10	13.41	1.59	----
E'	15	7.60	1.39	----	15	12.45	1.82	0.05
D'-E'	10	-0.72	-0.12	----	10	-0.96	-0.12	----

7h. Comparison of clusters by soil potassium (using t-test)

Groups	Top soil				Sub soil			
compared	d.f.	$\bar{X}_1-\bar{X}_2$	t	P	d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A'-B'	18	-0.13	-0.13	----	18	0.08	0.36	----
C'	18	-0.05	-0.16	----	18	-0.17	-0.81	----
D'	14	0.31	0.91	----	14	-0.27	-0.81	----
E'	18	0.16	0.59	----	18	-0.11	-0.52	----
B'-C'	15	0.08	0.22	----	15	-0.25	-1.92	0.05
D'	10	0.44	1.02	----	10	-0.35	-1.46	----
E'	15	0.29	0.83	----	15	-0.19	-1.76	0.05
C'-D'	10	0.36	1.03	----	10	-0.10	-0.42	----
E'	15	0.21	0.75	----	15	0.06	0.54	----
D'-E'	10	-0.15	0.60	----	10	0.16	0.76	----

7i. Comparison of clusters by soil sodium (using t-test).

Groups	Top soil				Sub soil			
compared	d.f.	$\bar{X}_1-\bar{X}_2$	t	P	d.f.	$\bar{X}_1-\bar{X}_2$	t	P
A'-B'	18	0.00	0.00	----	18	-0.06	-4.62	0.0005
C'	18	0.03	1.00	----	18	-0.03	-2.00	-----
D'	14	0.10	1.70	----	14	0.00	0.00	-----
E'	18	0.06	2.00	0.05	18	-0.02	-0.87	-----
B'-C'	15	0.03	0.50	----	15	0.06	3.00	0.005
D'	10	0.10	1.00	----	10	0.10	3.33	0.0025
E'	15	0.06	1.00	----	15	0.04	1.33	-----
C'-D'	10	0.07	1.16	----	10	0.04	1.33	-----
E'	15	0.03	1.0	----	15	-0.02	-0.67	-----
D'-E	10	-0.04	0.67	----	10	-0.06	-1.50	-----