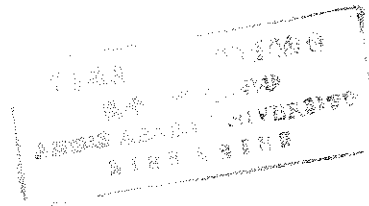


**COMPARATIVE STUDY OF THE
VEGETATION COMPOSITION OF Mt.
ALUTU AND Mt. CHUBBI ALONG
ALTITUDINAL GRADIENT**

By

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**A thesis submitted to the School of Graduate studies of
Addis Ababa University in partial fulfillment of the
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ABSTRACT

Comparative study of the vegetation composition of Mt. Alutu and Mt. Chubbi along altitudinal gradient was performed. Seventy-one, 20m x 20m stands, thirty-seven from Mt. Alutu and thirty-four from Mt Chubbi were selected systematically and all plants in the stands were recorded as present. Cover abundance value for trees, shrubs, and herbs was estimated. In addition trees and shrubs were counted. Environmental factors (altitude, slopes degree and slope aspect) were measured. The vegetation data from both mountains were merged and analyzed using the program SYNTAX. The utility program was employed to analyze species diversity. Eight homogenous clusters of stands were recognized. The resulting clusters were interpreted as community types and given provisional names after two or three dominant species. The clusters of the stands were compared for their averaged environmental factors using Tukey's family error rate test.

The clusters of stands were found to show the highest degree of contrast due to variation in altitude, i.e. in Mt. Alutu and Mt. Chubbi the main vegetation gradient is caused by differences in altitude. The altitude gradient is associated with changes in slope degree. In the present study sites altitude to larger extent, and slope degree to a lesser extent were found to be the major determinants of vegetational variation, whereas, slope aspect was less important.

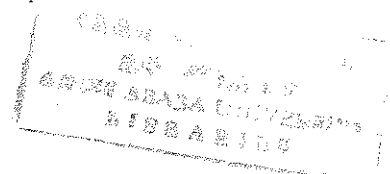
I. INTRODUCTION

1.1. Justification and Background

A number of authors have attempted to define vegetation ecology and vegetation. Among these are Polunin (1960), Greig-Smith (1964, 1983), Mueller-Dombois and Ellenberg (1974), Taylor (1984), Forman and Godron (1986), Noy-Meir and van der Maarel (1987) and Crawley (1997). The above authors viewed vegetation ecology as the study of plant communities or vegetation and the subject matter, which is vegetation, is viewed as the entire plant communities consisting of many species. Functionally vegetation is an organised and an integrated whole than the individual species, and, therefore, possesses properties, which are not necessarily found in the species themselves. This shows us that vegetation is a holistic system in its own right. Vegetation is the most obvious feature of the earth's surface and forms the immediate environment of man and his domestic animals. Therefore, all animal life depends on it for existence.

According to Noy-Meir & van der Maarel (1987) the main aspects of vegetation that are interest are classified as follows.

1. Structure, physiognomy, life forms
2. Diversity, dominance
3. Spatial variation in species composition, species distribution relation, scale of patterns
4. Temporal variation, stability.



Each of these aspects involves the relations to their environment. Therefore, vegetation is a function of several environmental factors and as such it is an indicator of the environment. It

responds not only to one environmental factor but also to an integrated group of factors (Mueller-Dombois and Ellenberg 1974, Messerli *et al.* 1980, Grime 1997). The identification of patterns in vegetation analysis can be done by variety of methods. Of these, the common ones are informal judgement, ordering of data tables, calculating similarity and association coefficients, classification and/or ordination techniques (Noy-Meir & van der Maarel 1987, Barbour *et al.* 1987).

Messerli *et al.* (1980) stated that the evidence from ecological studies on mountain vegetation could be a source of indirect climatic information. Eventhough the fluctuation of the level of the lakes can be a sensitive indicator of climate (Grove *et al.* 1975) emphasis should also be given to floristic composition. Because fluctuation in lakes level or even the drainage of the whole basin may have been due to volcanic or tectonic events (Bishop 1971 cited in Gasse *et al.* 1975). As explained by Messerli *et al.* (1980) vegetation associations and their boundaries are closely related to annual and seasonal fluctuations in climatic elements. Hence mountain areas can be recognised as ecological as well as climatic islands and differ markedly from the surrounding lowlands. Troll (1959) and Lauer (1975) both cited in Messerli *et al.* (1980) in support of the same idea explained that within a specific floristic regions the vertical distribution of plant species or associations are in many respects directly related to a particular combinations of climatic factors.

Vegetation study enables us to build a mental picture of an area under investigation and also to permit the comparison as well as ultimate classification of different units of vegetation (Kershaw 1973). Shimwell (1984) pointed out that vegetation analysis has five main objectives, which enable us to understand:

1. The plant communities of an area
2. The relationship between communities
3. How plant communities relate to and express their environment
4. How individual plant species are distributed within these communities.
5. How the communities develop and function as organised living system.

Studies on the vegetation of some parts of Ethiopia have been made taking different factors into consideration, altitude and climate being the most important. Some of these are Russ (1945), Breitenbach (1961, 1963), Beals (1968), Sebsebe Demmisew (1980), Zerihun Woldu (1980; 1985), Friis *et al.* (1982), Hailu Sharew (1982), Friis (1986), Tewolde Berhan G/Egziabher (1986), Lisanework Nigatu (1987), Zerihun Woldu *et al.* (1989), Zerihun Woldu & Mesfin Taddese (1990), Zerihun Woldu & Backeus (1991), Tamrat Bekele (1994a, b) and Menassie Gashaw & Masresha Fetene (1996). Although most researchers aimed at distinguishing ecologically homogeneous types, the objectives of these works were not exactly similar. Nevertheless, the contributions made by these authors towards the understanding of the vegetation of Ethiopia are of paramount significance. Although much effort has been made on the vegetation ecology of the country, no previous research into the vegetation of the present study sites has been made. Information on the vegetation composition of the study sites along altitudinal gradient does not exist. One of the aims of this work, therefore, is providing information on the vegetation along altitudinal gradients on these volcanic mountains.

This study has the following particular objectives:

A. Main Objective:

The Comparison of the vegetation composition of Mt. Alutu and Mt. Chubbi along

altitudinal gradient.

B. Specific objectives:

To gather basic vegetation data of Mt. Alutu and Mt. Chubbi

To study vegetation composition along altitudinal gradient on Mt. Alutu and Mt. Chubbi.

To compare the vegetation of the floor of the Rift Valley with elevated areas within the Rift Valley.

To study environmental factors along altitudinal gradient and determine which ones play the greatest role in limiting distribution of plants in association with altitude.

1.2. Location and Geology of the Study Areas

The study was conducted on Mt. Alutu ($7^{\circ}46'N$, $38^{\circ}47'E$) and Mt. Chubbi at ($7^{\circ}10'N$, $38^{\circ}27'E$) which are located in the Wonji fault of the Main Ethiopian Rift Valley. The Wonji fault is a belt of late-Quaternary extensional faulting (Mohr 1967, 1971, Mohr and O'Donnel 1984).

A Rift Valley is an elongated sunken area with a characteristic width of 30-60 kms that has run between parallel faults (McConnel 1967). However, according to Mohr's (1962, 1967) report the width of the Ethiopian Rift Valley exceeds the above figure. He reported that the width of the Ethiopian Rift Valley is 90 kms at Lake Shalla, 80 kms at Lake Awassa and 70 kms at Lake Abaya. Hence the average distance separating the eastern and western escarpments is about 80 kms.

The Ethiopian Rift Valley system is part of a system of down faulted troughs passing through

East Africa, the Horn of Africa, the Red Sea, Israel, Jordan and then Syria. This covers 5,000 kms in North-South directions. The East African part of this system extends 4,000 kms South-Southwest from the junction of the Red Sea and Gulf of Aden to the Zambezi River (Mohr 1962, McConnel 1972). The Ethiopian Rift System that extends from Lake Chamo in the South to Afar in the North is the most typically developed part of the East African Rift System (Mohr 1963). The Rift Valley of Southern Ethiopia runs NNE from Kenya frontier for 600 kms to the Koka dam on the Awash River (Grove *et al.* 1975).

Figure 1 shows map of the study areas.

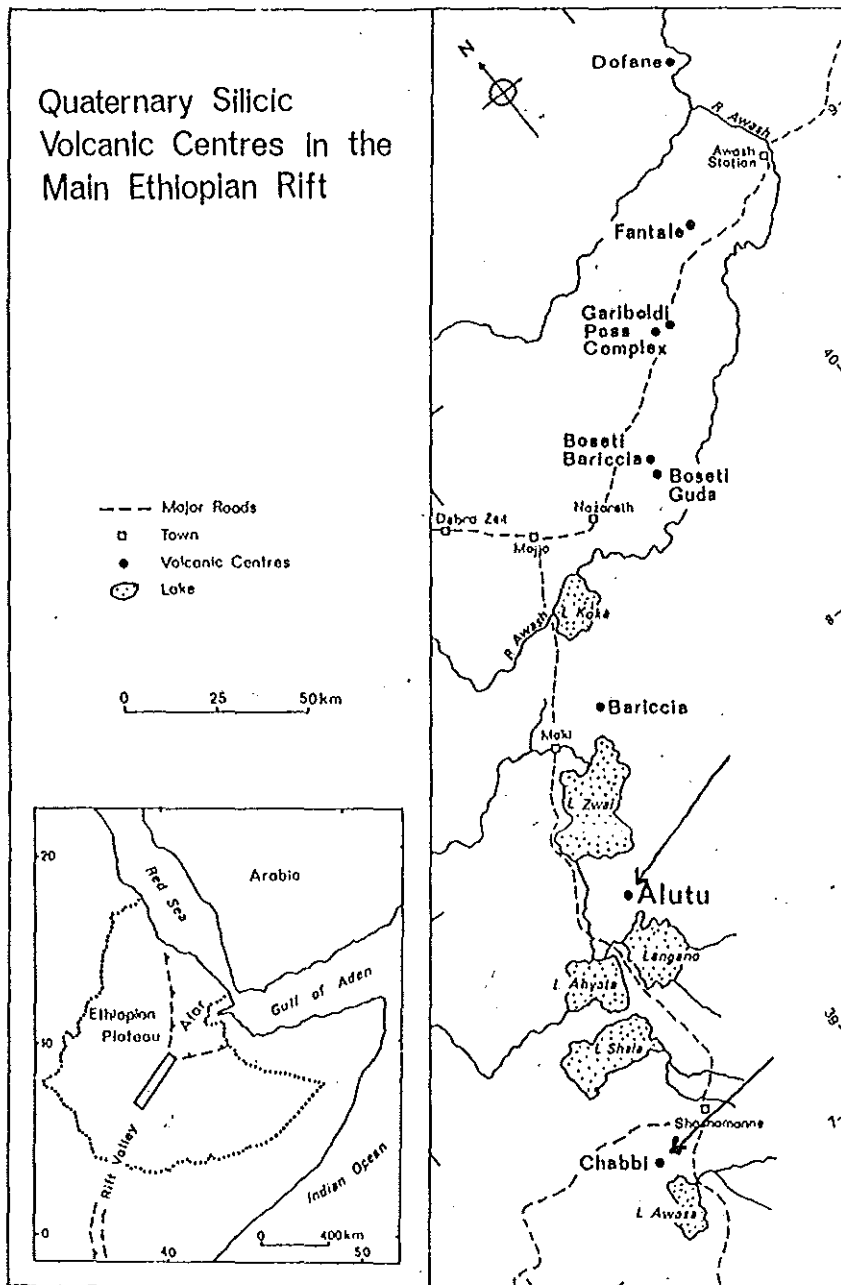


Figure 1 Map of the study areas (adopted from Dakin, F. & Gibson, I. L.)

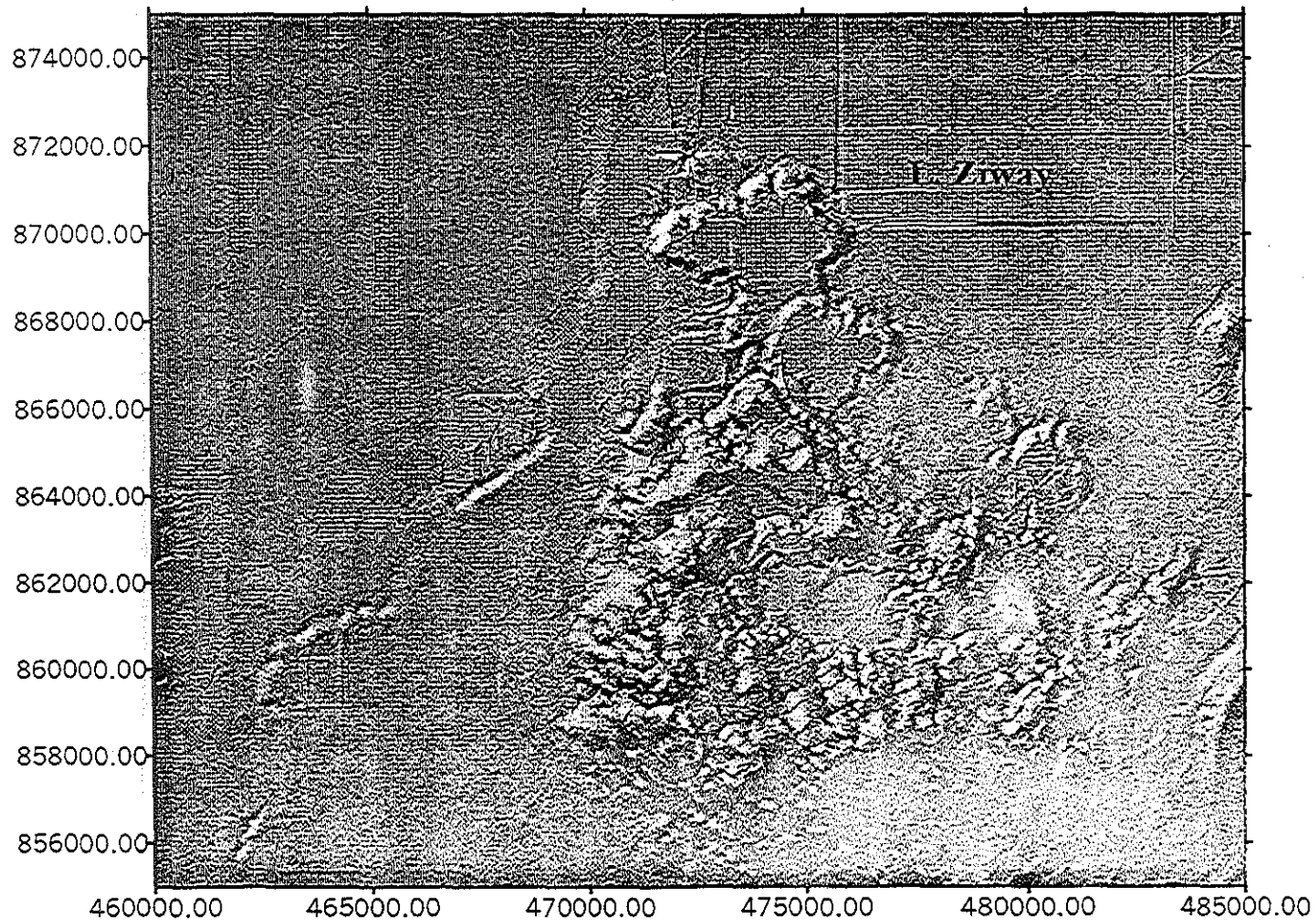
Grove (1971) has reported the presence of several large and dormant volcanoes within and around the basin occupied by the paleolake in the main Ethiopia Rift valley. These volcanoes in the Wonji fault are about one million years old and composed of silicic ash flow tuffs with minor air-fall tuffs and lava (Dakin & Gibson 1971, Mohr 1971). The tuffs are typically composed of pumice inclusive of glass shards, lithic clasts, and mineral crystals, dominantly feldspar (Dakin & Gibson 1971, Mohr 1971, Mohr and O'Donnell 1984).

Mohr (1966a, 1971) suggested that in the late tertiary, the Galla Lake basin was continuous with Lake Awassa and Lake Abaya basins to the South and with the Awash drainage to the North. This episode was followed by down faulting of the Rift, volcanism and transverse arching of the Rift floor, creating basins of internal drainage. As a result, the four Rift Valley lakes (Ziway, Langano, Abiyata and Shalla) were separated during early Pleistocene period. Grove (1971) and Gasse *et al.* (1980), however, reported that the main Ethiopian Rift Valley from Lake Ziway to Lake Awassa seems to have been occupied by single huge lake during late Pleistocene. Grove (1971) further explained that about 9,240 years ago Lake Abiyata, Langano and Shalla were united and were linked to Ziway and about 5,630 years ago the three lakes (Abiyata, Langano, and Shalla) were still united. Lake Ziway, Abiyata, Langano and Shalla were united together to form one huge lake during late Pleistocene and Holocene period (Geze 1975). The palaeolakes Ziway-Shalla covers 2,690 km² (Geze 1975). The Rift Valley lakes fluctuate in their water level with time (Grove *et al.* 1975). The development of eastern escarpment was probably coincident with the formation of the Shalla caldera and the silicic cones of Bora, Alutu and Chubbi (Mohr 1971).

mountain is obtained looking westwards from the Shashamane-Awassa road. Chubbi is a composite volcano of obsidian lava and pumice ash flows and beds and covers an area of about 65 km² with the highest point being 2,304 m.a.s.l (Mohr 1966a, b). Figure 5 and Figure 6 show shaded relief and contour map of Mt. Chubbi respectively.

According to Mohr (1966a), Dakin & Gibson (1971), Tesfaye Chernet (1982) and Mengesha Tefera *et al.* (1990) the two mountains are acidic and rhyolitic volcanic centres. Mt. Alutu and Mt. Chubbi are Pleistocene events (Tesfaye Chernet 1982). As far as their geology is concerning, they are composed of obsidian pitchstone, pumice, ignimbrite, tuffs, rhyolitic lava flows and subordinate trachytic flows (Mohr 1966a, Dakin & Gibson 1971, Tesfaye Chernet 1982, Mengesha Tefera *et al.* (1990). The geology of the two mountains is more or less the same.

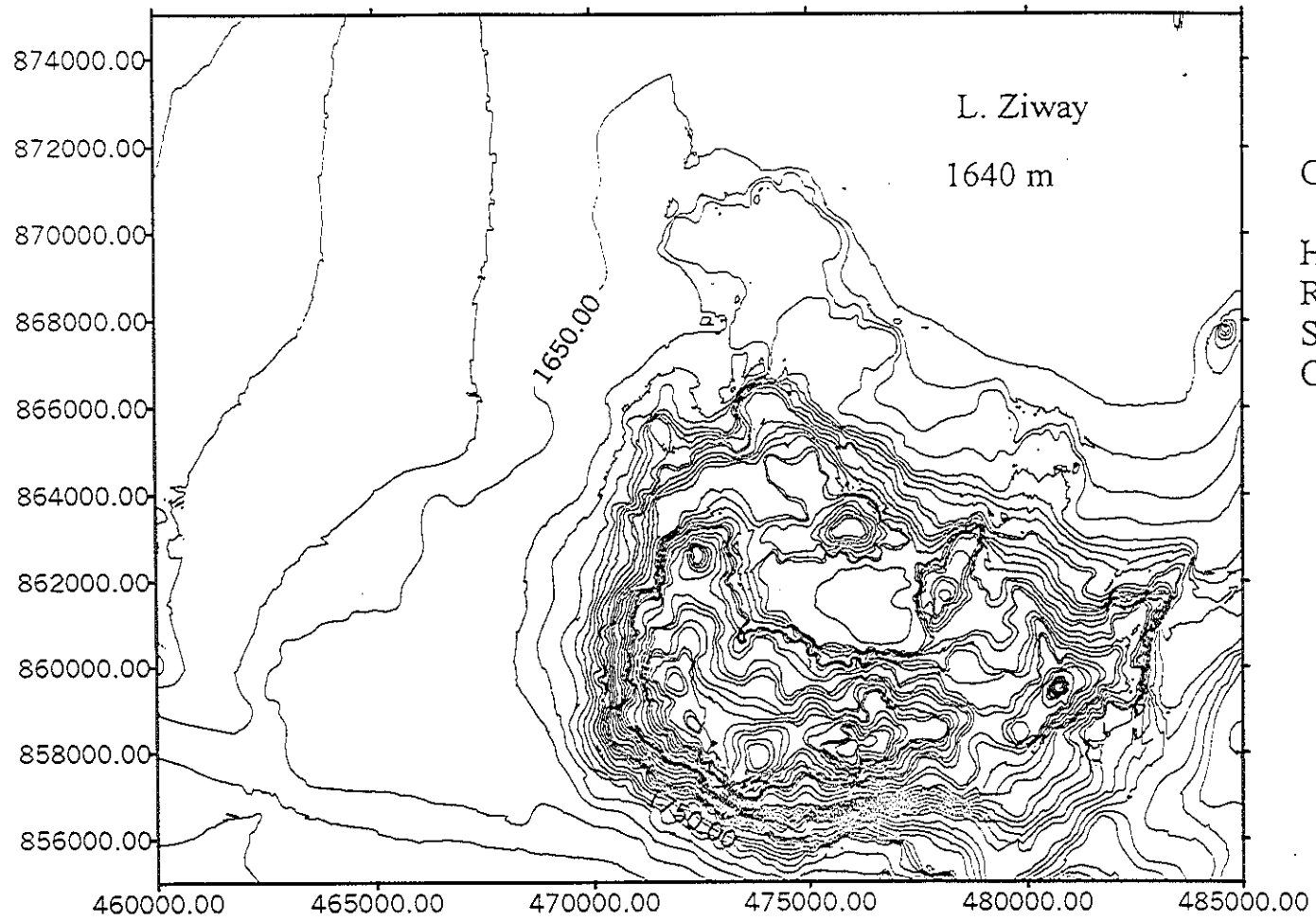
Comparative study of the vegetation composition of Mt. Alutu and Mt. Chubbi is of interest because both mountains have undergone similar geologic origin, surrounded by Rift Valley lakes and are separated from each other by three great lakes of the Rift Valley (Abiyata, Langano and Shalla).



Grid Information

Highest Peak = 2385 m
Reference System = UTM
Scale = 1:50,000

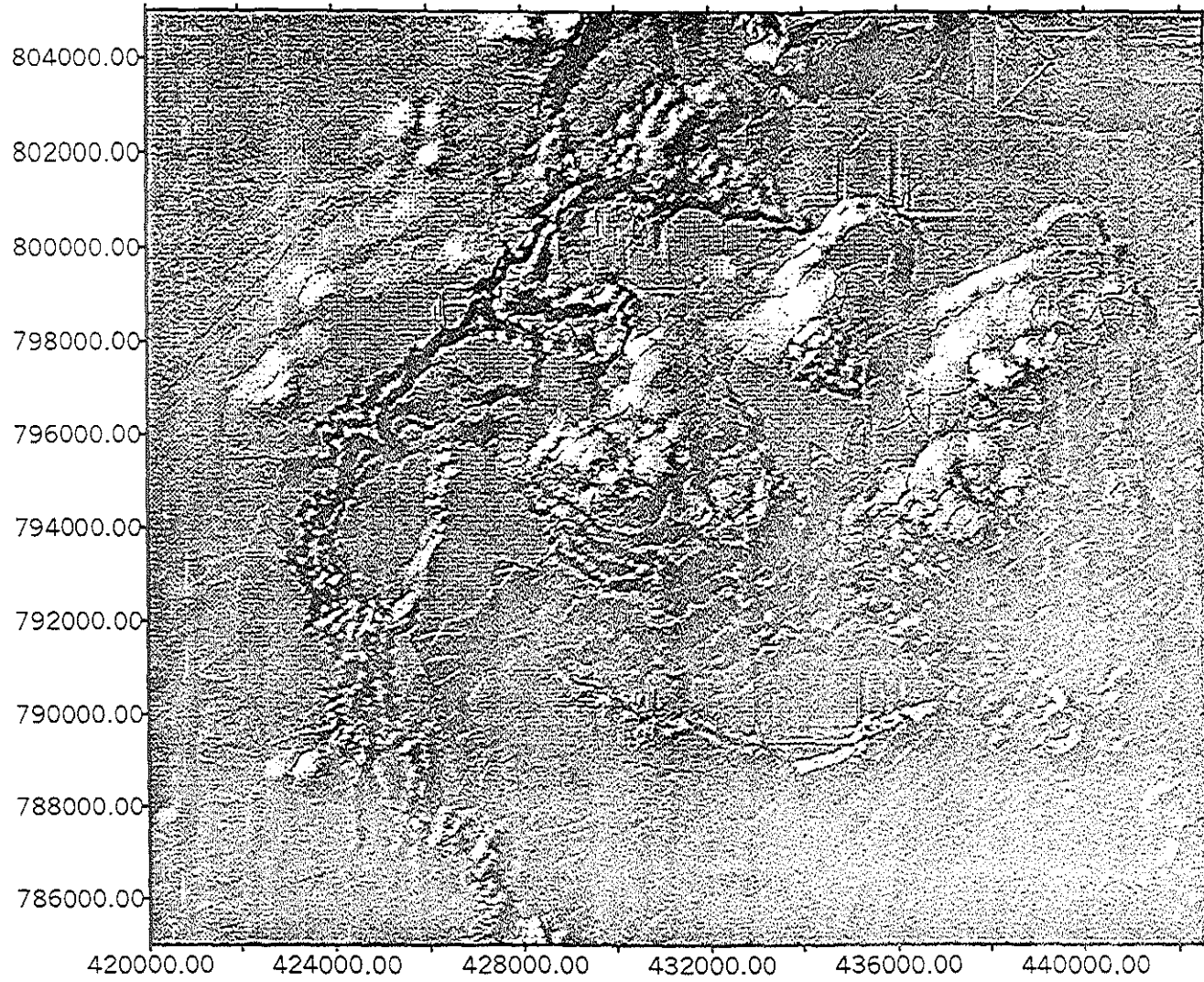
Figure 3. Shaded relief of Mt. Alutu



Grid Information

Highest peak = 2385 m
Reference System = UTM
Scale = 1:50,000
Contour Interval = 20 m

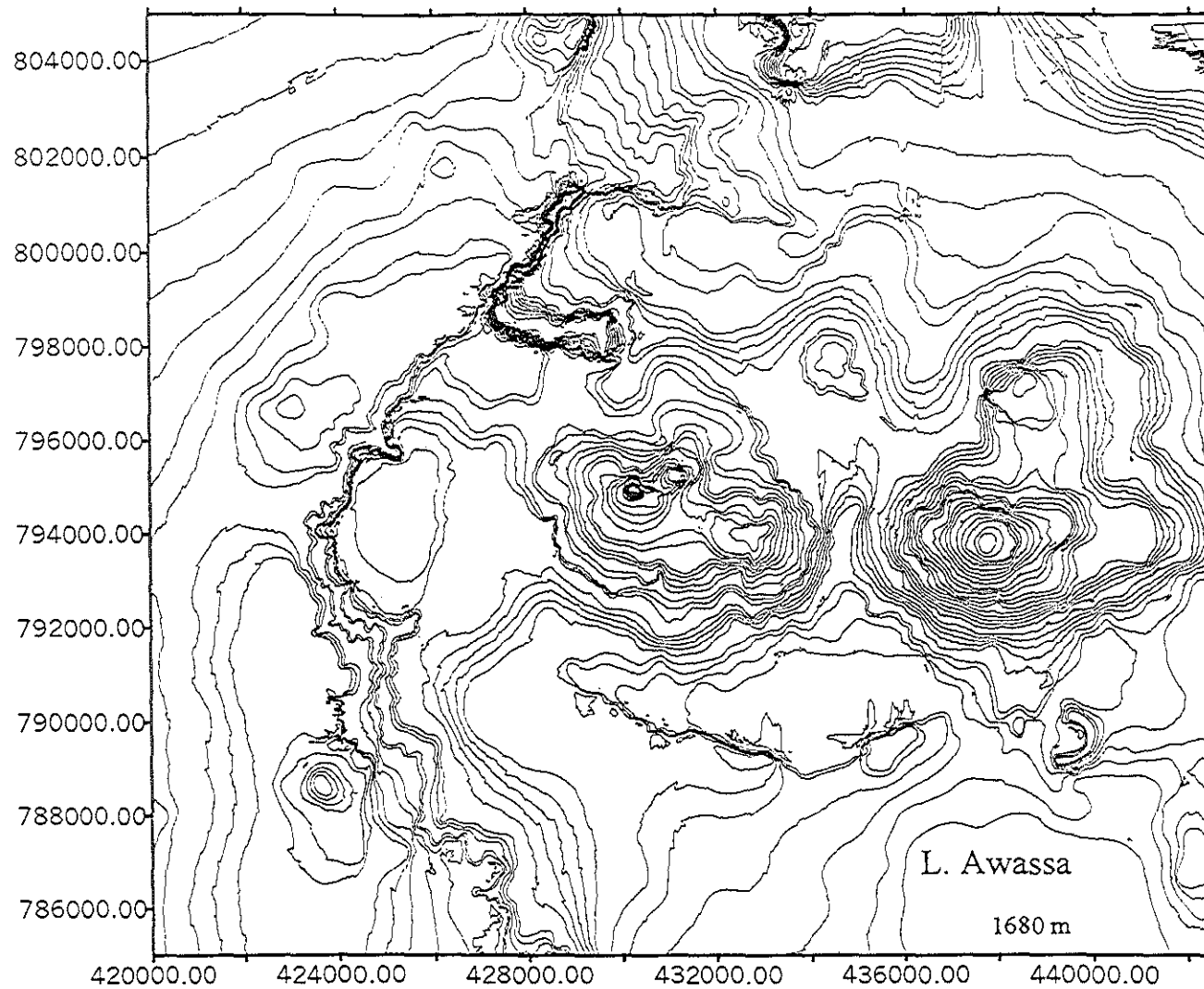
Figure 4. Contour map of Mt. Alutu



Grid Information

Highest Peak= 2303
Reference System = UTM
Scale = 1:50,000

Figure 5. Shaded relief of Mt. Chubbi



Grid Information

Highest peak = 2303 m
Reference system = UTM
Scale 1: 50,000
Contour interval = 20 m

Figure 6 Contour map of Mt. Chubbi

2. LITERATURE REVIEW

2.1. Climate and Vegetation of the Ethiopian Rift Valley

The climate of the Rift Valley of Ethiopia varies markedly over quite short distances (Grove *et al.* 1975) from semi-arid to hyper-arid climate (Gasse *et al.* 1980). The Mean annual rainfall varies altitudinally. It is a few millimetres in the areas below sea level in Afar, less than 300 mm near Stefanie (Chew Bahir), less than 600 mm in the vicinity of Lake Ziway more than 1600 mm at the high margins of the Rift (United Nations 1965, Grove *et al.* 1975, Kingham 1975). Therefore, rainfall increases with altitude in the Rift Valley. Both the time of onset and duration of the rains in the Rift Valley show latitudinal pattern. From March to June, Southeasterly winds from Indian Ocean bring heavy rain to South of 6.5°N. Further North, the main rains last from July to September. In South of Lake Abaya rain falls again in September and October (Gasse *et al.* 1980).

Air temperatures and evaporation decline markedly with altitude, although exposure and windiness may exert some modifying influence (Makin *et al.* 1975). The mean lapse rate is estimated to be 5.5°C per 1000 m (United Nations 1973). Temperature and elevation show a correlation of -0.9478 and the regression equation is $Y = 30.388041 - 0.006171X$ (Ronald 1997). Annual evaporation from the lake surface is believed to be 1,600 mm at Awassa, 2, 000 mm at Ziway and 3,000 mm at Beseka (United Nations 1973, Makin *et al.* 1975, 1976). The climatic episode that took place during three million years appears to have played an important role in development of the vegetation in the Rift Valley. The climatic gradient has resulted in a predominantly altitudinal patterns of vegetation belts, now greatly disturbed by human

interference. In the driest parts of the Afar, plant life is restricted to sparse tussocks of grass. Within the Main Rift, the vegetation ranges from *Acacia* woodland to dry thorn bushlands in the more arid areas. Climbing up the mountainous flanks on the escarpments, one successively encounters *Combretum* shrub-grasslands, remnants of *Afrocarpus* or *Juniperus* forests, *Hagenia-Hypericum* forest, and finally, beginning at about 3,000 m, Ericaceous scrub and Afroalpine heath (Gasse *et al.* 1980). According to Grove *et al.* (1975) the vegetation in the Rift Valley is open *Acacia* woodland in the neighbourhood of the lakes, tall forest trees on the shoulders of the Rift, grassland on the plateau and heath, tussock grass and tropical alpine on the high mountains. The common woodland species in this area are *Acacia* spp., *Lannea* spp., *Euclea schimperi*, *Dodonaea angustifolia* and *Dobera glabra*. The commonest grasses in deciduous woodlands are *Hyparrhenia* spp. and *Themeda triandra*. A recent study (Zerihun Woldu and Mesfin Tadesse 1990) shows that before the extensive depletion of the natural vegetation, the tree-shrub vegetation in the lakes region of the Main Ethiopian Rift Valley to be of four types. These are *Acacia albida* dominated type; high altitudinal vegetation type, which is dominated by *Olea europaea* subsp. *cuspidata*, *Acokanthera schimperi*, *Acacia etbaica*; low altitudinal deciduous vegetation type, which is dominated by *Acacia tortilis*, *Acacia seyal* and *Balanites aegyptiaca* and finally *Euphorbia candelabrum*, *Croton dichogamus* and *Solanum schimprianum*, dominated type.

2.2. Island Biogeography

The history of island organisms begins with isolation (Carlquist 1965). Plant species which appear to be non-African can be found on Africa highest mountains. This can be achieved by long-distance dispersal (Deshmukh 1986), perhaps by means of seeds carried by migratory birds.

An approach called Island Biogeographic theory has emerged quite recently (Simberloff and Wilson 1970) to deal with such vegetation types. In this approach the number of species on an island is related directly to three factors in the following order: the island's area, its isolation, and its age (Simberloff and Wilson 1970). The basic island area effect in island biogeographic theory has been considered to be mainly due to habitat diversity. In most cases, larger islands simply have more habitats therefore, support more species (Simberloff and Wilson 1970). However, there is also an area effect in the sense that even when habitat diversity does not differ, somewhat more species are typically found on large than on small islands (Simberloff 1976). Finally one major factor determining species diversity on an island is the history and present regime of disturbance (Carlquist 1965). Islands with evidence of considerable human disturbance activity often have fewer species than without such activity. However, not all islands respond in the same manner to disturbances (Simberloff and Wilson 1970).

There is a dynamic relationship between the species immigration and species extinction on islands (Mac Arthur and Wilson 1967 cited in Scott 1984). Species immigration is a function of distance while extinction is a function of island area. With more species present on an island, hence increased competition, the rate of colonisation of new arrivals would be lower, and the rate of extinction of species would be higher (Brown and Kodric-Brown 1977, Putman 1984, Forman and Godron 1986). It was additionally proposed that islands near a species source would have more diversity than isolated islands, because the rate of arriving species and colonists would be higher on nearby islands. The equilibrium is high on large, near islands and low on small, distant ones (Crawley 1997).

The changes in species composition on island can be large. New species arrive continually, but

few became established. Local extinction results from lack of suitable habitats and erosion (Heatwole and Levins 1973). Some islands could be flat while others could be mountainous. Mountainous islands have more species than the flat ones of the same size. The relationship between species diversity and islands size is curvilinear, that is, there is a rapid initial increase through the smaller island size and a slight, but continued, increase through the larger size (Heatwole & Levins 1973).

2.3. Effects of Topographic Factors on Vegetation

Topographic factors are one of the physiographic factors that are introduced by the structure conformity, and behaviours of the earth's surface - e.g. by topographic space-related features such as altitude and slope (Polunin 1960; Scott 1974). Topographic features act on local vegetation largely through climatic or edaphic features. Polunin (1960), Riley and Young (1966), McLean and Cook (1968), Misra (1974) and Avila (1992) agree on the fact that strong topographical relief tends to produce marked local climates, summits for example being very different in these respects from sides of mountains, and narrow valleys from open plains. Quite apart from the tendency to greater windiness and exposure at higher altitudes, the air and soil temperatures tend to get lower and the relative humidity greater as we ascend with atmospheric pressure decreasing and heat radiation increasing in intensity (Toumey 1947, Oasting 1956, Hedberg 1964, Daneil Gamatchu 1986). Altogether climatic variation becomes more and more extreme and rapid with increasing altitude. Such local climate changes would not take place if it were not for the topography.

The change of temperature gives rise to altitudinal zonation of vegetation. In addition



mountainous regions usually have more rainfall, higher relative humidity, and greater wind speeds. Mountain regions have mainly steep slopes and thin, rocky soils. Because of this the vegetation on mountain regions have shallow roots (Riley and Young 1966). Therefore, altitude is an important environmental factor which, by affecting temperature, radiation, moisture and atmospheric pressure, influences the growth and development of plants and vegetation distribution and composition (Toumey 1947, Oasting 1956).

Because of the tendency for temperature to fall with increasing altitude, the vegetation occurring in tropical mountains may be more like the flora of colder regions than that of the surrounding lowlands (Mooney 1974, Cox and Moore 1980, Avila 1992). Therefore, it can be concluded that the same species tend to recur together wherever a particular habitat repeats itself. In other words, areas that are climatically similar but geographically isolated will be characterised by similar plant forms.

The land features affect the environment to a very great extent. Moisture gradient, light, temperature, air pressure and other related climatic factors of the environment are influenced not only by altitude but also by slope direction and slope degree as well (McLean and Cook 1968, Misra 1974 Barbour *et al.* 1987). The precipitation caused by rising moisture-laden winds along the mountain slopes increases up to an altitude of about 3,000 meters and beyond this height the rain progressively decreases. The slope facing the wind ward side receives more rainfall while the leeward facing slope is generally drier (Misra 1974). Therefore, the direction of prevailing winds may also play an important part in determining the character of the flora (McLean and Cook 1968). Hence the slope of the ground may alter the character of the vegetation by affecting the intensity of light, moisture differences, run-off, and the amount of soil water and erosion.

Thus slope is one of the most important environmental factors 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 (Toumey 1947, Thompson and Troech 1978).

The steepness of a slope largely determines the stability of the surface, retention of water and has an effect on aspect. Thus, in the Northern hemisphere, a steep South-facing slope will receive the strong midday sun's ray more or less perpendicularly, while a steep North-facing slope may receive only oblique and weak morning and evening rays, or perhaps none at all (Barbour *et al.* 1987). These differences often have a marked effect, especially on the water and temperature conditions in the two places, and consequently on the vegetation. Steep slopes are constantly being eroded and may continually expose new surfaces to weathering Gentle slopes restrict transport and often enhance development of deep, strongly developed soils (Barbour *et al.* 1987).

In general, from the above discussions it is possible to conclude that altitude affects climate and its effect on temperature varies considerably according to prevailing conditions, especially, the aspect and steepness of slope. Altitude, exposure to wind and to a lesser extent disturbance were found to be the major determinants of vegetational variation, whereas parent rock and inclination were less important (Fernandez-Palacios & de Nicolas 1995).

2.4. Multivariate Techniques for Vegetation Analysis

2.4.1. General

Vegetation involves many species and environmental factors with complex relationships. Multivariate techniques are employed to study the complex nature of plant communities, with

the general objectives of summarising large complex data sets obtained from community samples, aiding in the interpretation of the data and the generation of hypothesis about community structure and variation (Lambert and Dale 1964; Greig-Smith 1964; 1983). These multivariate methods have shown an enormous increase in development and application since the last few decades. Among these multivariate methods employed to study the complex nature of communities, ordination and classification are the two main and basic strategies.

For a long time it was believed by some ecologists (e.g. Clements 1916, Braun-Blanquet 1932, Odum 1971) that vegetation is composed of certain distinct and fairly discrete plant communities. A belief in the discrete community-unit hypothesis enabled them to identify, describe and classify the plant communities. This view regards communities as having a degree of internal organization which jointly modifies the environment with sharp delimitation from other communities (Odum 1971). The continuum concept, on the other hand, as considered by Ramensky (1924), Gleason (1926), Curtis & McIntosh (1951) and Whittaker (1967) regards species individuality and community continuity (Mueller-Dombois and Ellenberg 1974). According to the idea of continuum concept vegetation changes continuously and is not really differentiated into distinct communities (Curtis and McIntosh 1951, McIntosh 1967). The phrase "continuum concept of vegetation" means that an uninterrupted series of elements form a sort of continuum, there being no sharp transition between communities and that species composition changes gradually from place to place and time to time (McIntosh 1967). Since then ecologists began to interpret vegetation not as communities, but as a complex but mostly continuous populations. However, there is no real conflict between the principles that communities are generally continuous with one another, and the practice of classifying these communities as a means of communication (Whittaker 1967, 1970, 1975).

It should, however, not be inferred that the continuum concept and the discrete community hypothesis are necessarily mutually exclusive. In contrast to an erroneous belief, even continuously variable communities do not exclude the classification approach. According to Gimingham (1968) and Monk (1968) both ordination and classification should continue to contribute materially to the elucidation of the complexities of vegetation. Therefore, the two methods are rather complementary 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 the vegetation (Greig-Smith *et.al* 1967, Orloci 1967, Whittaker 197, Digby and Kempton 1994). This study concerns classificatory techniques to analyse the vegetation data.

2.4.2. Classification

Classification, as multivariate technique to analyse ecological communities, groups similar sample stands into types (Whittaker 1972) and aims at grouping individual stands into categories by producing final groups which are as homogeneous in composition as possible (Greig-Smith 1980). The stands that are closely similar with one another form one class, which is separated from other such classes that also consist of similar stands. The properties common to a group of similar stands are then abstracted to serve as a description of that class. Therefore, the abstracted class properties may be compared to the average or mean of a set of values when combined with a measure of range. For practical and scientific validity, the abstracted class features should adequately describe the individual members of each class (Greig-Smith 1964, Mueller-Dombois and Ellenberg 1974, Digby and Kempton 1994). This technique is primarily qualitative. However, since this makes it too broad or too narrow for practical purpose, it is necessary to

consider the quantity of more prominent species (Greig-Smith 1964). This means that it provides a useful summary when complemented by an ordination (Orloci 1967, Whittaker 1972, Digby and Kempton 1994). Although classification implies discontinuity in composition, in practice, it often leads to the concept of vegetation as varying continuously in composition but emphasise the commoner occurrence of certain variants (Greig-Smith 1964).

Various techniques of vegetation classification have been discussed by several authors such as Whittaker (1962), Pielou (1969), Shimwell (1971), Mueller-Dombois and Ellenberg (1974) Greig-Smith (1964, 1980, 1983), Gold-smith and Harrison (1976), Gauch (1982), and Digby and Kempton (1994). According to Gauch (1982) Classification techniques are subdivided into three groups. These are table arrangement, non-hierarchical and hierarchical. Mueller-Dombois and Ellenberg (1974), and Westhoff and Maarel (1978) give detailed considerations of table arrangement. This subdivision is the earliest classification technique in community ecology. It has an advantage in that it exhibits at once both the general features and full detail 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). The aim is to arrange the species in the sequence that brings species together that are similar in their distribution and also, to arrange the samples in the sequence that brings samples together that are similar in composition. Besides its advantage, it has certain drawbacks. Some of these are; the result is relatively subjective (Kershaw 1973, Gauch 1982) and the application to unfamiliar species and unknown vegetation is difficult (Westhoff and Maarel 1978).

When there is no particular advantage in the groups or species of sites being arranged in a

hierarchy, a non-hierarchical method of classification, where groups have no joint structure, may then be preferred (Gauch 1982, Digby and Kempton 1994). Here samples or species are arranged to clusters, bringing similar samples or species together (Pielou 1969). With this technique it is the structure of the individual groups, which is optimised. Its aim is to produce the most efficient groupings regardless of the route by which they are derived (Greig-Smith 1983). For those applications in which homogeneity of groups is of prime importance, the non-hierarchical techniques are attractive. This method is, however, followed by computational difficulties (Williams 1971, Digby and Kempton 1994).

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). Therefore, the groups are themselves arranged into a hierarchy, say K groups are part of a separate grouping into (K-1) groups, and so on (Digby and Kempton 1994). It optimises a route between the entire population and the set of individuals of which they are composed. Hierarchical classification techniques are divided into three namely: Monothetic divisive, polythetic divisive and polythetic agglomerative (Williams *et al.* 1966, Williams 1971, Gold-Smith and Harrison 1976, Everitt 1980, Greig-Smith 1980, 1983, Gauch 1982).

According to Williams and Lambert (1959) 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 single species. Williams and Lambert (1960) presented a Monothetic divisive procedure, associations 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). This procedure has the disadvantage that it is

liable to misclassification (Kershaw 1961, Gittings 1965, Ivimey-Cook and Proctor 1966, Hill *et al.* 1975) and it is also followed by computational difficulties (Digby and Kempton 1994). This leads to agglomerative hierarchical methods, often collectively called 'cluster analysis' (Digby and Kempton 1994).

Polythetic divisive classification procedures use information on all species (Williams 1971, Williams and Lambert 1959, 1960). 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 clusters contain only one sample or some specified small number of samples (Digby and Kempton 1994).

Polythetic agglomerative classification techniques also use information on all species. However, these 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 (Lance and Williams 1966, Orloci 1967, Pritchard and Anderson 1971, Gauch and Whittaker 1981, Digby and Kempton 1994). Polythetic agglomerative methods proceed by scanning the whole data set and by examining the relationship between possible pairs of individual ($1/2n(n-1)$) where n = number of samples. At any particular stage the methods fuse individuals or groups of individuals which are most similar (or closest) (Sokal and Sneath 1963, Goodall 1978). These methods cluster on the basis of overall similarities. Because of this, 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. The precise sorting strategy that is used to direct the path taken by the hierarchy also varies. Several measure of similarity (or distance) function is currently in use. These include, single linkage,

average linkage complete linkage, centroid sorting and minimum variance clustering (Sokal and Sneath 1963, Williams and Dale 1965, Pritchard and Anderson 1971, Goodall 1978, Everitt 1980, Greig-Smith 1983, Digby and Kempton 1994). According to Digby and Kempton (1994) starting from the full inter-unit similarity matrix, all agglomerative methods begin by joining the two most similar units into a single group. The similarity of this group and all the other units are then calculated. This is where the methods differ. At the second stage the largest remaining similarity, among either two units or the new group and another unit, determines the next join. This process repeats until there are only two groups, or clusters, which, are finally merged (Digby and Kempton 1994). The final result from any clustering procedure depend both on the initial choice of similarity measure used for comparing units and the choice of criterion for defining group similarity. It also depends on the stopping rule for terminating the procedure.

Hierarchical procedures are known to be less cumbersome and more readily interpretable (Williams *et al.* 1966, Greig-Smith 1983). A drawback of the hierarchical approach (Lambert and Williams 1966), however, is that the decisions made are irrevocable. 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). Some ecologists e.g. Goodall (1953) and Crawford and Wishart (1968) have come around the problem by designing probabilistic of fusion among clusters that have been separated and have become associated with different branches of the dendrogram (see also Zerihun *et al.* 1998).

It is now evident that an enormous number of classification techniques have been developed (Whittaker 1962, Gauch 1982, Digby and Kempton 1994). The choice among the techniques

depends on the research purpose, size of the 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 the data of the present study.

3. DATA COLLECTION AND TREATMENT

A reconnaissance survey and data collection trips were made to each study sites between December 20, 1998 and March 18, 1999. During the field trips specimens were collected and pressed for herbarium identification at the National Herbarium in Addis Ababa University. Environmental factors (altitude, slope degree and slope aspect) were also recorded. Both study sites were a composite of pumic ash and obsidian rock (Mohr 1966a). Soil data were not collected for this reason.

3.1 Vegetation Data

Following systematic sampling technique (Slingsby and Cook 1992) transects were made along altitudinal gradient starting at 1750 meters a.s.l on Mt. Alutu and at 1800 meters a.s.l on Mt. Chubbi. A total of seventy one 20 x 20 m relevés, 37 from Mt. Alutu and 34 from Mt. Chubbi were established at 50 meters altitudinal difference starting from the lowest altitude. At each altitudinal level three quadrats were established with horizontal distance of about 150 meters from each other.

The plant specimens found within each quadrat were recorded as present. Trees and shrub species were counted and then their cover abundance was estimated. The cover abundance of herbs was also estimated. Specimens were then collected and pressed for Herbarium identification. Specimens were then identified by comparing them with already identified specimens in the National Herbarium in Addis Ababa University and by referring to various

3.2 Environmental Data

To investigate the habitat of each quadrat, the following environmental parameters were measured.

1. Altitude above sea level was measured using Everest altimeter.
2. Slope degree was measured using a SUUNTO clinometer.
3. Slope aspect was measured using a SUUNTO compass.

In addition to these topographic aspects of the environment, position of each quadrat was measured using GPS (Ground Position System) so that one can depict them on the map. The records are given in appendix 1.

Because Mt. Alutu and Mt. Chubbi were a composite of pumic ash and obsidian rock (Mohr 1966a; Dakin & Gibson 1971) it became impossible to collect soil samples.

3.3. Statistical Treatment

Prior to the analysis of the vegetation data, the plant species collected from Mt. Alutu and Mt. Chubbi were merged and considered as one data set. The data on trees, shrubs and herbs, which were originally estimated in the field in the form of percentage of cover abundance values, were converted into Braun-Blanquet (1932) scale as codified by Maarel (1979) which extends from 1 to 9. These are:

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.
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. 25.5 - 50% cover of the total area.
8. 50.5 - 75% cover of the total area.
9. 75.5 - 100% cover of the total area.

In this study average linkage clustering procedure was used to classify the vegetation data. The computer program employed was SYNTAX (Podani 1988). Similarity ratio was used as a resemblance index where as average linkage was used as a clustering technique.

$$\text{Similarity Ratio, } SR_{ij} = \frac{\sum X_{k,i} \cdot X_{k,j}}{(\sum X_{k,i}^2 + \sum X_{k,j}^2 - \sum X_{k,i} \cdot X_{k,j})}$$

Average linkage clustering is hierarchical polythetic agglomerative procedure in which pairs of stands are fused on the basis of their similarities being highest or dissimilarities being lowest. It progresses by successive fusion until all stands are fused into a single group, building a hierarchy from the bottom.

To calculate the arithmetic mean values for the measured environmental factors of each distinct plant community type the measured values for all stands that make up the particular community type were added up and averaged for altitude, degree of slope and aspect of slope.

Before calculating the mean values for aspect of the slope, it was codified following Zerihun Woldu *et al.* (1989) as follow; N=0, NE=1 E=2, SE=3, S=4, SW=3.3, W=2.5, NW=1.3 and Ridge top=4.

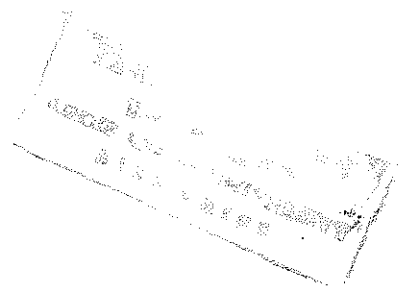
Analysis of variance (ANOVA) was performed to detect significance differences among the different means of the environmental factors of each community type. Tukey's family error rate test was performed to test significant contrast between clusters. The analysis on species diversity was performed using a utility program. Statistical analyses were performed with the program SPSS.

4 RESULTS AND DISCUSSIONS

4.1 Vegetation Analysis

A total of 140 species belonging to 55 families were recorded from seventy-one stands in both study sites. The data set was then subjected to the multivariate package SYNTAX. The dissimilarity ratio levels at which ecologically meaningful major clusters show up were determined.

Eight major clusters designated as 1, 2, 3, 4, 5, 6, 7, and 8 were identified from the SYNTAX output at dissimilarity level above 0.60 (fig. 7). Communities can be defined using various characteristics. One of these approaches is classification by dominant species. Classification by dominant species is a natural and widely used approach. Community types defined by their dominant species can be termed dominance-types, but often they are called simply "types" (Whittaker 1975). According to Whittaker (1975) classifying communities by dominant species is the easiest way of classifying communities. Based on this information each cluster distinguished in this study was described as types and named after two dominating plant species. By dominant species here we mean a species with high mean cover-abundance value shown in Table 1.



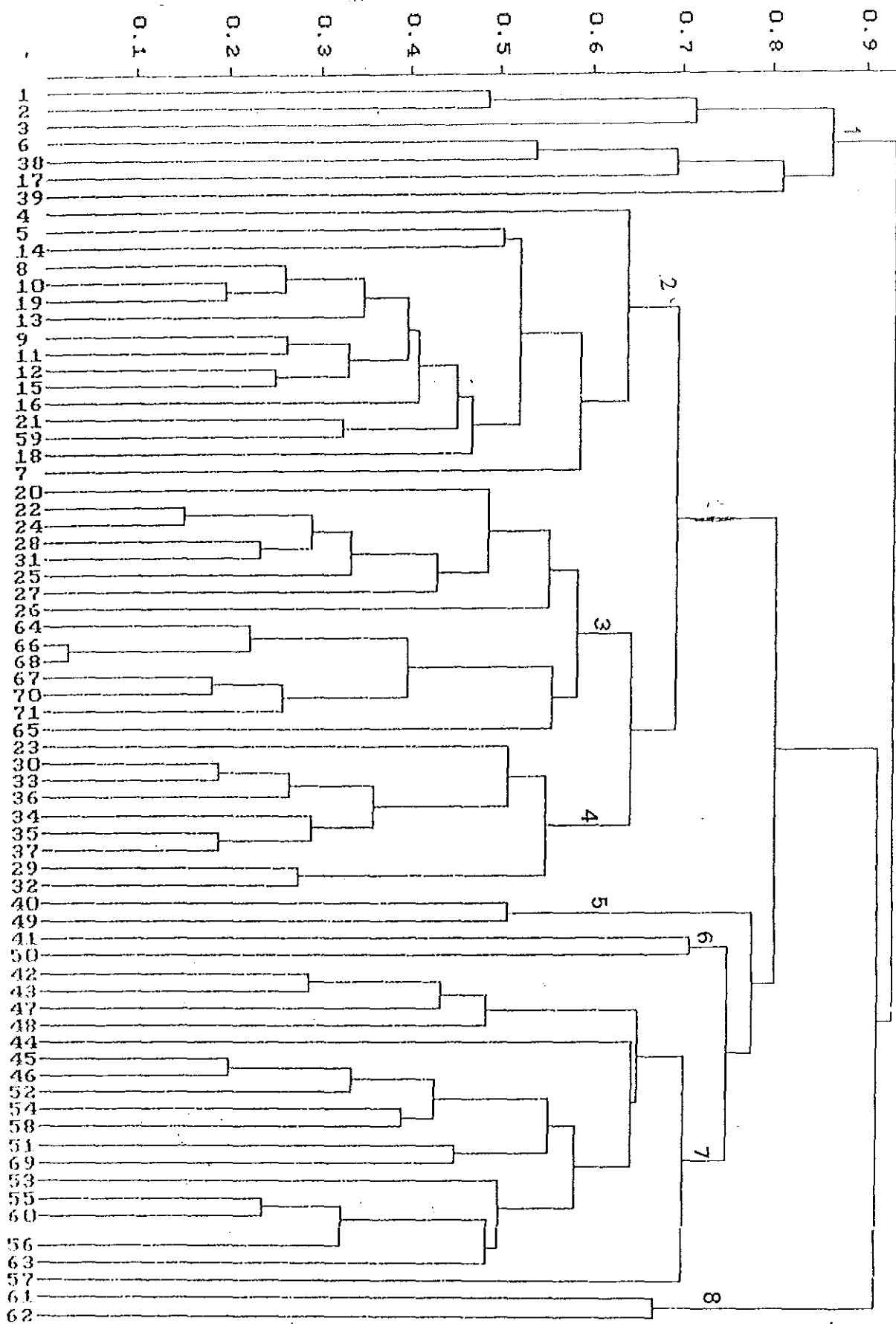


Figure 7. Dendrogram of stand groups of vegetation composition found on Mt. Alutu and Mt. Chubbi merged together. (Y-axis represents the dissimilarity level while X-axis represents stands).

Table 1. List of species with mean values of greater than or equal to one at least in one of the community types.

Species	Clusters							
	1	2	3	4	5	6	7	8
	Releve numbers							
	7	16	15	9	2	2	18	2
<i>Clusia abyssinica</i>	3.55	0	13	0	3.0	1.0	2.44	0
<i>Capparis fascicularis</i>	2.54	2.45	.13	0	0	0	.11	0
<i>Balanites aegyptiaca</i>	2.53	2.0	.13	0	0	0	.11	1.0
<i>Dodonaea angustifolia</i>	0	3.40	1.87	1.44	0	0	2.61	0
<i>Erica arborea</i>	0	.68	6.80	4.11	0	1.0	4.06	0
<i>Protea gaguedi</i>	0	.31	5.20	7.44	0	0	.55	2.50
<i>Bothriochloa insculpta</i>	.28	.81	.86	6.44	0	0	0	0
<i>Hyparrhenia hirta</i>	.57	0	.40	0	8.0	4.0	4.11	0
<i>Olea europaea</i>	.57	.31	1.20	.44	2.0	6.50	4.83	0
<i>Hymenodictyon floribundum</i>	.28	.12	0	0	0	5.50	2.28	1.50
<i>Myrsine africana</i>	0	.68	4.33	1.33	0	2.50	3.56	1.0
<i>Agawia salicifolia</i>	0	0	.33	0	0	0	.16	3.50
<i>Hypericum revolutum</i>	0	.12	2.27	0	0	2.0	2.44	3.0
<i>Bersama abyssinica</i>	0	0	0	0	0	0	0	2.50
<i>Rhus natalensis</i>	1.27	.25	.13	0	0	0	.33	0
<i>Heliotropium sp.</i>	1.19	.37	0	0	0	0	0	.0
<i>Ficus sycomorus</i>	1.0	0	0	0	0	0	0	0
<i>Kotschyia recurvifolia</i>	.28	.37	0	1.11	0	0	0	0
<i>Psydrax schimperiana</i>	.28	1.15	0	0	0	1.0	1.11	0
<i>Heteromorpha trifoliata</i>	0	.31	3.87	3.56	0	1.50	1.56	0
<i>Pteridium aquilinum</i>	0	.12	1.66	1.0	0	0	.72	0
<i>Andropogon sp.</i>	0	0	1.40	1.22	0	0	0	0
<i>Rhus abyssinica</i>	0	.50	0	1.0	0	0	0	0
<i>Ozoroa insignis</i>	.71	.93	0	.33	2.0	0	.72	0
<i>Rumex nervosus</i>	.57	.93	.13	.22	2.0	2.0	.88	0
<i>Centela asiatica</i>	0	0	0	0	2.0	0	0	0
<i>Gomphocarpus fruticosus</i>	0	0	0	0	1.0	0	.11	0
<i>Rubia cordifolia</i>	0	0	0	0	1.0	0	.11	0
<i>Sida ovata</i>	0	.25	0	0	1.0	0	.55	0
<i>Trema orientalis</i>	0	0	.13	0	1.0	0	0	0
<i>Ximenia americana</i>	0	.12	0	.22	1.0	0	.33	0
<i>Ostostegia frutescens</i>	.28	0	.53	0	1.0	1.0	.22	0
<i>Croton macrostachyus</i>	.57	0	0	0	1.0	0	.38	0
<i>Acacia seyal</i>	.57	0	.26	0	1.0	0	.44	0
<i>Tagetes minuta</i>	.57	0	0	0	1.0	0	.11	0
<i>Hypoestes forskalii</i>	.42	0	0	0	1.0	1.0	.44	0
<i>Celtis africana</i>	.28	0	0	0	1.0	0	.11	0
<i>Cynoglossum coenilecum</i>	.28	0	0	0	1.0	1.0	.33	0
<i>Acacia abyssinica</i>	0	0	0	0	1.0	0	.11	0
<i>Acacia tortilis</i>	0	0	0	0	1.0	0	.11	0
<i>Hyparrhenia anthistirioides</i>	0	.12	.13	0	0	4.0	0	0
<i>Entada abyssinica</i>	0	.12	0	0	0	2.50	.50	0
<i>Schefflera abyssinica</i>	0	0	0	0	0	2.50	.38	0
<i>Jasminum abyssinicum</i>	.57	.75	1.20	.0	0	2.0	1.67	2.0
<i>Clematis simensis</i>	.57	0	.13	0	0	2.0	1.0	2.0
<i>Vernonia utricifolia</i>	.28	0	0	0	1.0	1.50	0	1.0
<i>Rhoicissus tridentata</i>	.85	0	.13	0	0	1.0	.77	1.0

<i>Maytenus senegalensis</i>	.71	0	0	0	0	1.0	.66	1.0
<i>Kalanchoe densiflora</i>	.57	.25	.13	0	0	1.0	.22	.0
<i>Achyranthus aspera</i>	0	0	0	0	0	1.0	0	0
<i>Girardinia diversifolia</i>	0	0	0	0	0	1.0	0	0
<i>Asparagus racemosus</i>	0	0	0	0	0	1.0	0.22	0
<i>Lansea fruticosa</i>	0	0	0	0	0	1.0	0	1.0
<i>Aristida adoensis</i>	0	0	1.80	0	2.50	0	6.44	0
<i>Melinis repens</i>	.42	0	.33	1.78	0	0	2.28	0
<i>Heteropogon contortus</i>	.71	0	.20	0	0	0	2.0	0
<i>Bidens prestinaria</i>	.57	0	.13	0	0	1.50	1.83	0
<i>Englerina woodfordioides</i>	.28	.25	.13	0	0	0	1.22	0
<i>Maytenus gracilipes</i>	0	0	0	0	1.0	1.0	1.11	0
<i>Lippia adoensis</i>	0	.12	0	.44	1.0	1.0	.33	2.0
<i>Osyris quadripartita</i>	0	.12	1.27	.66	0	0	.61	2.0
<i>Olinia rochetiana</i>	0	0	.26	.44	0	0	1.33	1.50
<i>Acacia lahai</i>	0	0	0	0	0	0	0	1.0
<i>Nuxia congesta</i>	0	0	.13	.22	0	0	.33	1.0
<i>Rubus apetalus</i>	0	0	.13	0	0	0	.11	1.0

The description of the plant communities recognized from the SYNTAX output based on the dominant species with their altitudinal distribution is as follows. By plant community here we refer to local assemblages of several plant species in a given area. Every plant community has its own characteristics and usually two or three particular species dominate in that community. The cluster numbers in the (Fig. 7) correspond to numbers of the community types in the subsequent discussion.

1. *Clusia abyssinica-Capparis fascicularis-Balanites aegyptiaca* community. *Clusia abyssinica-Capparis fascicularis-Balanites aegyptiaca* community is found at altitude from 1,750-1,800 m.a.s.l at both mountains. This is the lowest altitude on both mountains. *Rhus natalensis*, *Heliotropium* spp. and *Ficus sycomorus* are also found in this community. The common grasses in the field layer includes *Melinis repens* and *Heteropogon contortus*

2. *Dodonaea angustifolia-Capparis fascicularis* community. Remarkably *Dodonaea angustifolia* L. f. occurred in all stands of the community. This community is found from 1,800-2,050 m.a.s.l at both mountains. *Balanites aegyptiaca*, *Psydrax schimperiana*, *Olea europaea*, *Erica arborea*, *Heteromorpha trifoliata* and *Ozoroa insignis* are also found in this community. Grass species are not common in this community.

3. *Erica arborea-Protea gaguedi* community. This community is found at altitude from 2,050-2,300 m.a.s.l at both mountains. Other species that commonly occur at this altitudinal range includes *Dodonaea angustifolia*, *Heteromorpha trifoliata*, *Myrsine africana*, *Olea europaea*, *Hypericum revolutum*, *Jasminum abyssinicum*, *Osyris quadripartita* and *Pteridium aquilinum*. *Andropogon* sp., and *Aristida adoensis* are common grasses in this community.

4. *Protea gagedi*-*Bothriochloa insculpta* community. This community is found at the highest altitudinal range, which starts from 2,200 up to 2,350 m.a.s.l. Other plant species, which occur commonly in this community, are *Erica arborea*, *Heteromorpha trifoliata*, *Dodonaea angustifolia*, *Myrsine africana*, *Kotschya recurvifolia*, *Rhus abyssinica* and *Pteridium aquilinum*. The most common grass species are *Bothriochloa insculpta*, *Melinis repens* and *Andropogon* sp.

5. *Hyparrhenia hirta*-*Clusia abyssinica* community. Seventy five percent of the stands are covered with a grass, *Hyparrhenia hirta* (L.) Stapf. The next dominant species of the community is *Clusia abyssinica* Jaub. & Spach. Other species, which commonly occur in this community, are *Acacia abyssinica*, *Centela asiatica*, *Olea europaea*, *Ozoroa insignis*, *Rumex nervosus* and *Aristida adoensis*. The altitudinal range of this community extends from 1,800 to 1,900 m.a.s.l. Relative to the other stands of the entire study site the stands of this community are found on more or less flat terrain.

6. *Olea europaea*-*Hymenodictyon floribundum* community. This community occurs in the altitudinal ranges from 1,850 and 2,200 m.a.s.l. The species that commonly occur in this community are *Myrsine africana*, *Clematis simensis*, *Entada abyssinica*, *Jasminum abyssinicum*, *Hypericum revolutum*, *Heteromorpha trifoliata*, *Rumex nervosus* and *Schefflera abyssinica*. The common grass species in the community are *Hyparrhenia anthistirioides* and *Hyparrhenia hirta*.

7. *Olea europaea*-*Erica arborea*-*Myrsine africana* community. This community occurs at altitude between 1,900 to 2,100 m.a.s.l. The species that commonly occur in this community

include *Clusia abyssinica*, *Ficus* spp., *Heteromorpha trifoliata*, *Hypericum revolutum*, *Hymenodictyon floribundum*, *Dodonaea angustifolia*, *Rhus natalensis*, and *Olinia rochetiana*. The common grass species in this community are *Melinis repens*, *Aristida adoensis*, *Hyparrhenia hirta* and *Heteropogon contortus*.

8. *Agaurea salicifolia* - *Hypericum revolutum*-*Bersama abyssinica* community. This community occurs at 2,050 m.a.s.l. *Protea gaguedi*, *Clematis simensis*, *Lippia adoensis*, *Jasminum abyssinicum* and *Osyris quadripartita* are the common species.

The arrangement of these communities in increasing order of altitude is *Clusia abyssinica*-*Capparis fascicularis*-*Balanites aegyptiaca* community, *Hyparrhenia hirta*-*Clusia abyssinica* community, *Dodonaea angustifolia*-*Capparis fascicularis* community, *Olea europaea*-*Erica arborea*-*Myrsine africana* community, *Olea europaea*-*Hymenodictyon floribundum* community, *Agaurea salicifolia*-*Hypericum revolutum*- *Bersama abyssinica* community, *Erica arborea*-*Protea gaguedi* community and *Protea gaguedi*-*Bothriochloa insculpta* community. *Clusia abyssinica*-*Capparis fascicularis*-*Balanites aegyptiaca* community constitutes the vegetation at the lowest altitude on both mountains and it is this plant community type that resembles in vegetation composition the lowlands of the Rift Valley. Associated species such as *Acacia seyal* and *Ficus sycomorus* are responsible for this similarity. On the other hand *Erica arborea*-*Protea gaguedi* community and *Protea gaguedi*-*Bothriochloa insculpta* community are situated on higher altitudes on Mt. Chubbi and on Mt. Alutu respectively. This reveals that *Protea gaguedi* dominates the higher altitude of the Rift Valley than does *Erica arborea*. *Erica arborea*-*Protea gaguedi* community type and *Protea gaguedi*-*Bothriochloa insculpta* community are highland vegetation in lowlands. As

the vegetation composition of these communities show, they resemble that of highland vegetation. The discrimination in vegetation composition between communities is due to high significant contrast in altitude. Because of tendency for temperature to fall with increasing altitude, the dominant vegetation inhabiting both mountains resembles more like the flora of highland than that of the surrounding lowlands. Therefore, it can be concluded that the same species tend to recur together, wherever particular habitat repeats itself.

From field observation of the vegetation composition of the study sites we can conclude that *Erica arborea* and *Dodonaea angustifolia* occurred throughout the entire altitude. However, this may not be observed in the communities from table 1 because of low cover abundance values. According to Tewolde (1986) *Erica arborea* is an indicator of unfavorable conditions at lower altitudes, example, in the pumiceous mountain, Mt. Bora, in the Rift Valley, where it occurs as low as 1,700 m. This also holds true for Mt. Alutu and Mt. Chubbi. Though, under natural conditions, *Erica arborea* forms community towards the upper edge of the forest, as it is also true in case of Mt. Chubbi, the upper edge of Mt. Alutu is relatively dominated by *Protea gagedi* than *Erica arborea*.

From the above result we may conclude that Mt. Alutu and Mt. Chubbi differ in their vegetation composition from the surrounding lowlands and resemble high land vegetation. The species on the mountains may have reached there by long-distance dispersal perhaps by means of seeds carried by migratory birds and other means from the nearby highlands such as the Arsi and the Bale Mountains.

From the plant community description given above it becomes evident that in the present

study sites, the vegetation composition is not homogeneous, i.e. there is non-uniformity (heterogeneity). This is attributable to altitude, giving rise to environmental gradient.

4.2 Community-Environment Relationship

Vegetation is interpreted as a function of several factors of the environment. The plant community is composed of individual plants, each of which comprises complex organs, tissues, and cells. The environment on the other hand is a complex of activating agents.

The classification technique identified the discontinuities in the vegetation and delimited the stands into clusters having similar vegetation composition. This was supported by the significant contrasts found between clusters as shown by the Tukey's family error rate test. There were, however, similar environmental conditions in the different clusters. Table 2 gives the ranking of each community with respect to the averages of all measured environmental factors of the stands of that cluster.

Table 2. Ranks of the final homogeneous clusters based on the average values of the environmental factors.

Community types	Altitude	Slope	Aspect
1	8	7	3
2	6	1	5
3	2	2	6
4	1	3	2
5	7	8	3
6	4	5	7
7	5	4	8
8	3	6	1

The major discrimination among the communities is due to altitude. The communities could be categorised into three groups based on altitude. Group 1, with altitude between 2,100 and 2,350 m.a.s.l. Communities 3 and 4, which are dominated by *Erica arborea-Protea gagedi* and *Protea gagedi-Bothriochloa insculpta* respectively, are included in this category. Group 2, with altitude between 1,900 and 2,100 m.a.s.l includes plant communities 2, 6, 7, and 8. *Dodonaea angustifolia*, *Capparis fascicularis* and *Olea europaea*, on both study sites are the dominant species in this range. *Hymenodictyon floribundum* are also dominant in this range on Mt Chubbi. Group 3 with altitude between 1,750 and 1,900 m.a.s.l includes plant communities 1 and 5 and is dominated by *Clusia abyssinica*, *Capparis fascicularis* and *Balanites aegyptiaca* on both mountains. In this range the community on Mt. Alutu is also dominated by *Croton dichogamus*.

Comparison of the communities based on the slope degree shows that plant community 1 is significantly different from communities 2, 3, and 7. Community 2 is significantly different from

5 and 7. Community 3 is also significantly different from 5 and 7. Communities 4, 6, and 8 do not show any difference with any of the communities. Communities 2, 3, and 7 are on steep slopes.

The result of the quantitative data using the utility program showed a decrease in the species diversity with the rise in altitude on Mt. Alutu and Mt. Chubbi. Table 3 shows Shannon-Weaver (1949) diversity index of the plant communities according to descending order of their species diversity. Shannon-Weaver diversity index can be calculated using the formula:

$$H' = -\sum p_j \log p_j$$

Table 3. Shannon-Weaver Diversity Index of Plant Communities.

Plant community types	H', Shannon-Weaver diversity index	H'/H'max
7	3.612	0.839
1	3.593	0.914
2	3.201	0.862
6	3.188	0.937
3	2.994	0.782
5	2.929	0.922
8	2.794	0.967
4	2.767	0.806

As shown in the above table (Table 3) plant community 7 has higher species diversity value than the rest while plant community 4 which occurred at high altitude has the lowest diversity value. Plant community from Mt. Alutu has more species diversity as compared to those of Mt. Chubbi.

This agrees with the view of Forman and Godron (1986) and Crawley (1997) in that, islands near species source would have more diversity than isolated islands. This is because the probability of species arrival on nearby island would be higher.

From the foregoing account, the community-environment relationships suggest that with increasing altitude, slope degree increase while slope aspect has no significant change. Consequently, the distribution of the vegetation types and their differences in floristic composition on Mt. Alutu and on Mt. Chubbi are attributed largely to variation in altitude and to a lesser extent by slope degree. Therefore the development of plant communities in localised areas is the result of the environmental influence.

5. CONCLUSION AND RECOMMENDATIONS

The major vegetation composition on Mt Alutu and Mt Chubbi have been described in this study by means of classification using computer program, SYNTAX. Eight plant communities have been distinguished and related to measured environmental variables.

The communities distinguished from Mt. Chubbi are: *Clutia abyssinica*–*Capparis fascicularis*–*Balanites aegyptiaca*, *Hyparrhenia hirta*–*Clutia abyssinica*, *Dodonaea angustifolia*–*Capparis fascicularis*, *Olea europaea*–*Erica arborea*–*Myrsine africana* , *Olea europaea*–*Hymenodictyon floribundum*, *Agauria salicifolia*–*Hypericum revolutum*–*Bersama abyssinica* and *Erica arborea*–*Protea gaguedi*. On the other hand the communities identified from Mt. Alutu are *Clutia abyssinica*–*Capparis fascicularis*, *Dodonaea angustifolia*–*Capparis fascicularis*, *Erica arborea*–*Protea gaguedi* and *Protea gaguedi*–*Bothriochloa insculpta*

Clutia abyssinica–*Capparis fascicularis*–*Balanites aegyptiaca*, *Dodonaea angustifolia*–*Capparis fascicularis* and *Erica arborea*–*Protea gaguedi* communities are found to be similar to both mountains. *Protea gaguedi*–*Bothriochloa insculpta* community was identified from Mt Alutu. *Hyparrhenia hirta*–*Clutia abyssinica*, *Olea europaea*–*Erica arborea*–*Myrsine africana*, *Olea europaea*–*Hymenodictyon floribundum* and *Agauria salicifolia*–*Hypericum revolutum*–*Bersama abyssinica* communities were identified from Mt. Chubbi.

Of the species described 50 species occurred on both mountains. The list of this species is given in appendix 4. Some were localised to only one or the other of the two mountains. Since the floristic list is not necessarily exhaustive, conclusions, regarding the composition of vegetation can not be definitive. Except for slope aspect, there was a significant variation in altitude and

slope degree between communities.

The vegetation of Mt. Alutu and Mt. Chubbi is predominantly that of highland vegetation rather than the neighbouring lowland. It has been subjected to intense and uninterrupted destruction (Personal communication with local people and observation). As a result the vegetation is subjected to degrading factors which reduce the vegetation cover and thus contribute to the desertification of the whole areas. Bush fire is a common incidence on both mountains but more on Mt. Chubbi.

The vegetation on Mt. Alutu and Mt. Chubbi should be conserved at least for the sake of biodiversity. Any rational use of the vegetation has to consider the requirements of local people and the production capacity of the environment. It is only then that, any conservation program would be realised. Certainly, this call for better land use planning as a means to avoid conflicts of interest between the future utilisation of the resource of the country and other development activities. However, this may require a multi-disciplinary technical co-operation. It should not be the task of the government alone, but should also require the social, environmental and economic information.

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APPENDICES

Appendix 1. Topographic data of the stands sampled.

Stand number	Study Site	Altitude (masl)	Slope (degree)	Slope aspect	Position
1	Alutu	1750	5	S	473423E 0855447N
2	Alutu	1750	7	SE	4743440E 0855593N
3	Alutu	1750	6	SE	476019E 0855182N
6	Alutu	1800	4	S	476129E 0856003N
38	Chubbi	1800	26	NE	442662E 0793865N
17	Alutu	2000	17	S	473938E 0856035N
39	Chubbi	1800	5	E	442912E 0793594N
4	Alutu	1800	29	S	473515E 0855761N
5	Alutu	1800	30	E	473588E 0856035N
14	Alutu	1950	23	E	476235E 0856595N
8	Alutu	1850	40	W	473655E 0856259N
10	Alutu	1900	37	SE	473796E 0856445N
19	Alutu	2050	36	W	473951E 0856987N
13	Alutu	1950	42	E	476235E 0856545N
19	Alutu	1850	18	E	475994E 0858487N
11	Alutu	1900	21	SW	475906E 0858611N
12	Alutu	1900	30	SE	475821E 0856656N
15	Alutu	1950	45	SE	475771E 0856751N
16	Alutu	2000	45	E	473678E 0856904N
21	Alutu	2050	27	S	472991E 0857245N

Contd.

59	Chubbi	2050	25	S	440987E 0793808N
18	Alutu	2000	30	S	472937E 0857165N
7	Alutu	1850	24	SE	473672E 0856217N
20	Alutu	2050	30	SW	473955E 0857361N
22	Alutu	2100	30	S	473996E 0857069N
24	Alutu	2150	35	E	474134E 0857151N
28	Alutu	2200	28	S	473248E 0857503N
31	Alutu	2250	33	S	473167E 0857551N
25	Alutu	2150	45	W	473070E 0857466N
27	Alutu	2200	36	E	474020E 0857267N
26	Alutu	2150	50	E	473029E 0857508N
64	Chubbi	2100	30	W	440291E 0794065N
66	Chubbi	2150	28	SE	439725E 0794105N
68	Chubbi	2150	30	S	439260E 0793908N
67	Chubbi	2150	23	SE	439784E 0794134N
70	Chubbi	2250	30	N	439253E 0794094N
71	Chubbi	2300	15	S	439216E 0794118N
65	Chubbi	2100	15	E	439430E 0793895N
23	Alutu	2100	40	S	473020E 0857419N
30	Alutu	2250	25	S	473804E 0857510N
33	Alutu	2300	23	S	473587E 0857650N
36	Alutu	2350	16	N	473440E 0857710N

Contd.

34	Alutu	2300	32	S	473339E 0857621N
35	Alutu	2350	3	E	473446E 0857777N
37	Alutu	2350	15	SE	473361E 0857644N
29	Alutu	2200	26	SW	473093E 0857460N
32	Alutu	2250	29	SE	473265E 0857529N
40	Chubbi	1800	0	0	441617E 0793314N
49	Chubbi	1900	5	E	441513E 0793309N
41	Chubbi	1850	15	W	442644E 0793800N
50	Chubbi	2200	17	W	440429E 0792645N
42	Chubbi	1850	21	NE	442732E 0794260N
42	Chubbi	1850	15	N	442622E 0794333N
47	Chubbi	2250	26	NE	439267E 0794243N
48	Chubbi	2300	34	N	439043E 0794702N
44	Chubbi	1900	34	E	442603E 0793835N
45	Chubbi	1900	4	E	442513E 0793778N
46	Chubbi	1900	10	E	442016E 0793619N
52	Chubbi	1950	14	S	441863E 0793666N
54	Chubbi	1950	4	SE	442476E 0793350N
58	Chubbi	2000	30	NE	440414E 0793647N
51	Chubbi	1950	20	E	442288E 0793650N
69	Chubbi	2200	10	SE	441153E 0793295N
53	Chubbi	1950	23	SE	441381E 0793638N
55	Chubbi	1950	15	S	440889E 0793385N

Contd.

60	Chubbi	2050	15	SW	440763E 0793735N
56	Chubbi	2000	26	S	441240E 0793713N
63	Chubbi	2100	18	SE	441131E 0793802N
57	Chubbi	2000	16	SE	440710E 0793620N
61	Chubbi	2050	21	S	440399E 0793585N
62	Chubbi	2050	10	S	439649E 0793656N

N=North
NE=North-East
S=South
SE=South-East
SW=South-West
E=East
W=West

Appendix 2. Stand composition of each cluster

Cluster	Stand composition	Study site
1	1,2,3,6,38,17,39	Alutu and Chubbi
2	4,5,14,8,19,13,9,11,12,15,16,21,59,18,7	Alutu and Chubbi
3	20,22,24,28,31,25,27,26,64,66,68,67,70,71,65	Alutu and Chubbi
4	23,30,33,36,34,35,37,29,32	Alutu
5	40,49	Chubbi
6	41,50	Chubbi
7	42,43,47,48,44,45,46,52,54,58,51,69,53,55,60,56,63,57	Chubbi
8	61,62	Chubbi

Appendix 3. Mean values of each parameter for final homogeneous clusters of the quantitative vegetation data.

Cluster	Number of stands	Altitude (masl)	Slope degree	Slope aspect
1	7	1807	10	3.0
2	16	1928	31	2.9
3	15	2163	30	2.8
4	9	2272	23	3.0
5	2	1850	2.5	3.0
6	2	2025	16	2.5
7	18	2002	18.6	2.3
8	2	2050	15.5	4

Appendix 4. Plant species recorded from both mountains.

Specimen code(s)	Scientific name of the specimen	Stands on which the specimen recorded
164,52	<i>Dodonaea angustifolia</i>	1,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,31,32,34,45,46,47,52,53,54,55,56,58,59,60,69,71
182,206,27,35	<i>Heteromorpha trifoliata</i>	4,5,7,8,9,10,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,37,41,45,46,47,48,51,52,53,58,59,65,66,67,68

Contd.

187,33	<i>Erica arborea</i>	4,5,7,8,9,10,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,37,41,44,45,46,51,52,53,54,55,56,57,58,59,60,68,69,70,71
202,32	<i>Myrsine africana</i>	5,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,27,28,29,30,31,32,33,41,42,43,44,45,46,47,48,50,51,52,53,,55,56,57,58,59,60,62,63,64,65,66,67,68,70,71
203,259,65	<i>Protea gagedi</i>	7,8,14,15,18,19,20,21,22,23,24,25,27,28,29,30,31,32,33,34,35,36,37,46,55,58,59,62,63,64,65,66,67,68,70,71
183,9	<i>Olea europaea</i>	4,5,6,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,24,33,36,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,63,64,65,67,69,70,71
192,22,48	<i>Melinis repens</i>	3,4,5,6,7,9,10,11,12,13,14,15,16,17,27,30,32,33,36,38,42,43,44,47,51,55,57,69
188,7	<i>Jasminum abyssinica</i>	4,5,7,8,9,10,12,13,14,15,16,17,18,19,20,21,22,24,38,39,41,42,43,44,45,46,47,48,50,53,55,56,57,58,59,60,61,62,63,65,66,67,68,69,70
200,40,86	<i>Osyris quadripartita</i>	5,7,8,9,10,11,14,16,18,19,20,21,23,24,28,29,30,31,35,36,44,56,57,60,61,62,63,64,66,67,68,70,71
199,59	<i>Pteridium aquilinum</i>	5,14,16,21,22,23,24,25,26,28,31,32,35,36,45,46,47,52,57,65,67,70
155,100	<i>Dichrostachys cinerea</i>	1,3,5,8,9,12,17,19,21,28,29,35,37,66,69
152,205,14,142	<i>Maytemus senegalensis</i>	1,3,4,5,6,8,14,38,39,42,43,47,48,50,55,57,69
258,31	<i>Maytemus spp.</i>	15,20,40,41,44,45,46,47,52,53,57,60,63

Contd.

159,1	<i>Clusia abyssinica</i>	1,5,6,7,9,10,11,12,14,15,16,17,3 8,39,40,42,43,44,45,46,47,48,49, 50,51,52,53,56,63,64
156,87,91	<i>Ximenia americana</i>	1,4,5,6,7,8,9,30,40,56,59,60,69
211,41	<i>Olinia rochetiana</i>	13,16,18,19,20,28,30,36,44,45,4 6,51,52,54,57,62,63,64
214,34	<i>Hypericum revolutum</i>	16,19,22,24,25,26,28,29,41,43,4 4,45,46,47,48,50,51,52,53,54,56, 58,59,61,62,63,64,65,66,67,68,6 9,70,
163,3	<i>Hypoestes forskalii</i>	1,2,3,4,5,6,38,42,43,47,50
150,123,125	<i>Acacia abyssinica</i>	1,2,3,5,17,40,49
153,127	<i>Capparis fascicularis</i>	1,2,5,6,9,48
154,111	<i>Balanites aegyptiaca</i>	1,2,6,17,38,46
184,55	<i>Ozoroa insignis</i>	4,5,7,8,32,40,42,45,47,48,49,55, 58,59
194,114	<i>Rhus natalensis</i>	4,5,6,7,9,27,39,42,47,48
189,227,25	<i>Rhus</i> spp.	4,5,7,8,9,16,17,29,30,32,33,39,4 1,42,43,44,45,46,47,48,49,50,51, 52,53,55,56,57,58,59,60,61,62,6 3,64,65,66,67,69,70,71
204,54	<i>Psydrax schimperiana</i>	7,9,13,14,15,45,47,48,50,51,55,5 6,60,63,69
181,79	<i>Acacia seyal</i>	2,4,17,27,39,40,43,48,49,50
209,18	<i>Rumex nervosus</i>	10,18,25,37,38,39,40,41,42,43,4 4,48,49,50,51,63,69
232,265,29	<i>Rhoicissus tridentata</i>	17,38,39,41,42,43,47,48,58,62,6 3,67,69
231,81	<i>Lippia adoensis</i>	17,30,35,49,50,53,56,61,62,69,
168,23	<i>Chloris virgata</i>	1,2,5,38
279,248,249,71	<i>Myrica salicifolia</i>	33,36,53
193,13	<i>Croton macrostachyus</i>	3,4,38,39,40,42,48
208,50,75	<i>Satureja punctata</i>	8,23,44
224,17	<i>Englerina woodfordioides</i>	15,16,38,44,47,48,69,52,53,55,5 6,57,58,59,60,63,65
256,37	<i>Hyparrhenia anthistiriodes</i>	18,28,41
175,138,77,74,76	<i>Indigofera arabica</i>	1,53
219,116,57,105,6,	<i>Vernonia</i> spp.	16,42,45,51,56,39,40,50,61,38,4 1
177,115	<i>Sida ovata</i>	1,40,42,43,47
191,11	<i>Ficus vasta</i>	4,38,42,47,52
174,8	<i>Kalanchoe</i> spp.	1,2,3,6,27,38,39,41,43,50
271,274,19,70	<i>Ficus</i> spp.	3,5,53,38,39,42,43,47,58,60
179,112	<i>Calpurnia aurea</i>	2,3,42

Contd.

222,223,36	<i>Clematis simensis</i>	16,39,41,42,43,44,47,48,50,51, 52,58,61,62,63,64
264,108	<i>Lannea</i> spp.	12,14,50,61
234,109	<i>Ocimum gratissimum</i>	17,46
195,139	<i>Leucas</i> spp.	4,65
253,95	<i>Nuxia congesta</i>	31,43,55,62,63,65
251,180,178,72,12	<i>Crotalaria</i> spp.	37,2,53,38,42,
221,250,140	<i>Tephrosia</i> spp.	16,36,65
275,113	<i>Celtis africana</i>	3,40,42

Appendix 5. Vegetation Data Collected From Mt. Chubbi.

Specimen code(s)	Scientific name of the specimen	Family	Quadrat
123,125	<i>Acacia abyssinica</i>	Fabaceae	40,49
107	<i>Acacia lahai</i>	Fabaceae	61
79	<i>Acacia seyal</i>	Fabaceae	39,40,43,48,49,50
126	<i>Acacia tortilis</i>	Fabaceae	40,48
141	<i>Achyranthus aspera</i>	Amaranthaceae	50
92	<i>Agauria salicifolia</i>	Ericaceae	61,62,63,64,65
98	<i>Allophyllus abyssinicus</i>	Sapindaceae	42,47,48,54,58,64,65,66,67,68
16,128	<i>Amphelocissus schimperiana</i>	Vitaceae	38,39
20,46	<i>Aristida adoensis</i>	Poaceae	42,43,44,45,46,47,48,49,51,52,53,54,55,56,57,58,60,63,64,66,68,69,70,71
121	<i>Asparagus racemosus</i>	Asparagaceae	47,48,50
111	<i>Balanites aegyptiaca</i>	Balanitaceae	38,46
106	<i>Bersama abyssinica</i>	Melanthaceae	50,60,61
44	<i>Bidens prestinaria</i>	Asteraceae	38,39,41,42,43,44,45,46,47,48,51,52,54,58,63,64
112	<i>Calpurnia aurea</i>	Fabaceae	42
127	<i>Capparis fascicularis</i>	Capparidaceae	48
113	<i>Celtis africana</i>	Ulmaceae	40,42
136	<i>Centella asiatica</i>	Apiaceae	40,49
130	<i>Chenopodium murale</i>	Chenopodiaceae	39
23	<i>Chloris virgata</i>	Poaceae	38
36	<i>Clematis simensis</i>	Ranunculaceae	39,41,42,43,44,47,48,50,51,52,58,61,62,63,64
1	<i>Clusia abyssinica</i>	Euphorbiaceae	38,39,40,42,43,44,45,46,47,48,49,50,51,52,53,56,63,64
72	<i>Crotalaria incana</i>	Fabaceae	53
12	<i>Crotalaria laburnifolia</i>	Fabaceae	38,42
13	<i>Croton macrostachyus</i>	Euphorbiaceae	38,40,42,48
4	<i>Cynoglossum coerulecum</i>	Boraginaceae	38,40,42,43,48,50,
100	<i>Dichrostachys cinerea</i>	Fabaceae	66,69
52	<i>Dodonaea angustifolia</i>	Sapindaceae	45,46,47,52,53,54,55,56,69,70,71
17	<i>Englerina woodfordioides</i>	Loranthaceae	38,44,45,46,47,48,52,53,55,56,57,58,59,60,63,65,69
42	<i>Entada abyssinica</i>	Fabaceae	42,43,44,50,58,59

Contd.

33	<i>Erica arborea</i>	Ericaceae	41,44,45,46,51,52,53,54,55,56,57,58,59,60,68,69,70,71
122	<i>Euclea schimperi</i>	Ebenaceae	47
70	<i>Ficus ovata</i>	Moraceae	53
19	<i>Ficus thommingii</i>	Moraceae	38,39,42,43,47,58,60
11	<i>Ficus vasta</i>	Moraceae	38,42,47,52
134	<i>Girardinia diversifolia</i>	Urticaceae	50
60	<i>Gomphocarpus fruticosus</i>	Asclipodiaceae	40,45
84,144,	<i>Helichrysum odoratissimum</i>	Asteraceae	56
27,35	<i>Heteromorpha trifoliata</i>	Apiaceae	37,41,45,46,47,48,51,52,53,58,59,65,66,67,68
88	<i>Heteropogon contortus</i>	Poaceae	39,42,43,48,55,57,60,65,69
43	<i>Hibiscus cannabinus</i>	Malvaceae	44
30	<i>Hymenodictyon floribundum</i>	Rubiaceae	39,41,42,43,45,46,47,48,50,51,52,54,58,59,62,63
37	<i>Hyparrhenia anthistirioides</i>	Poaceae	41
21	<i>Hyparrhenia hirta</i>	Poaceae	38,39,40,41,42,43,44,48,49,52,53,55,56,60,63,70,71
34	<i>Hypericum revolutum</i>	Hypericaceae	41,43,44,45,46,47,48,50,51,52,53,54,56,58,59,61,62,63,64,65,66,67,68,69,70
3	<i>Hypoestes forskalii</i>	Acanthaceae	38,42,43,47,48,49,50
74,76,77,138	<i>Indigofera arabica</i>	Fabaceae	53
7	<i>Jasminum abyssinicum</i>	Oleaceae	38,39,41,42,43,44,45,46,47,48,50,53,55,56,57,58,59,60,61,62,63,65,66,67,68,69,70,
8	<i>Kalanchoe densiflora</i>	Crassulaceae	38,39,41,43,50
15	<i>Laggera pterodonta</i>	Asteraceae	38
108	<i>Lannea fruticosa</i>	Anacardiaceae	50,61
139	<i>Leucas argentea</i>	Lamiaceae	65
81	<i>Lippia adoensis</i>	Verbenaceae	49,50,53,56,61,62,69

Contd.

31	<i>Maytenus gracilipes</i>	Celastraceae	40,41,44,45,46,47,52,53,57,60,63
14,142	<i>Maytenus senegalensis</i>	Celastraceae	38,39,42,43,47,48,50,55,57,69
22,48	<i>Melinis repens</i>	Poaceae	38,42,43,44,47,51,55,57,69
71	<i>Myrica salicifolia</i>	Myricaceae	53
32	<i>Myrsine africana</i>	Myrsinaceae	41,42,43,44,45,46,47,48,50,51,52,53,55,56,57,58,59,60,62,63,64,65,66,67,68,70,71
95	<i>Nuxia congesta</i>	Loganiaceae	43,55,62,63,65
109	<i>Ocimum gratissimum</i>	Lamiaceae	46
9	<i>Olea europaea</i>	Oleaceae	38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,63,64,65,67,69,70,71
41 97	<i>Olinia rochetiana</i>	Oliniaceae	40, 44,45,46, 49, 51,52,54,57,62,63,64,65,66,67,68,69,
2	<i>Ostostegia fruticosa</i>	Lamiaceae	38,40,41,43,47,65,66,67,68
40,86	<i>Osyris quadripartita</i>	Santalaceae	44,56,57,60,61,62,63,64,66,67,68,70,71
55	<i>Ozoroa insignis</i>	Anacardiaceae	40,42,45,47,48,49,55,58,59
131	<i>Pavetta abyssinica</i>	Rubiaceae	39,57
5	<i>Pavonia urens</i>	Malvaceae	38
45,69,96	<i>Pentas schimperana</i>	Rubiaceae	44,51
80,99	<i>Premna schimperi</i>	Verbenaceae	53
65	<i>Protea gagedi</i>	Protaceae	46,55,58,59,62,63,64,65,66,67,68,70,71
54	<i>Psyrax schimperiana</i>	Rubiaceae	45,47,48,50,51,55,56,60,63,69
59	<i>Pteridium aquilinum</i>	Dennstaediaceae	45,46,47,52,57,65,67,70
29	<i>Rhoicissus tridentata</i>	Vitaceae	38,39,41,42,43,47,48,58,62,63,67,69
114	<i>Rhus natalensis</i>	Anacardiaceae	39,42,47,48

Contd.

25	<i>Rhus retinorrhea</i>	Anacardiaceae	39,41,42,43,44,45, 46,47,48,49,50,51,5 2,53,55,56,57,58,59, 60,61,62,63,64,65, 66,67,
67	<i>Rhynchosia resinosa</i>	Fabaceae	46
49	<i>Rubia cordifolia</i>	Rubiaceae	40,44
94	<i>Rubus apetalus</i>	Rosaceae	62,63,67
18	<i>Rumex nervosus</i>	Polygonaceae	38,39,40,41,42,43, 44,48,49,50,51,63, 69
50,75	<i>Satureja punctata</i>	Labiatae	44
26	<i>Schefflera abyssinica</i>	Araliaceae	41,45,46,50,52
115	<i>Sida ovata</i>	Malvaceae	40,42,43,47
104	<i>Solanum incanum</i>	Solanaceae	47,70
10	<i>Tagetes minuta</i>	Asteraceae	30,39,40,42
140	<i>Tephrosia pentaphylla</i>	Fabaceae	65
20	<i>Themeda triandra</i>	Poaceae	38
102	<i>Trema orientalis</i>	Ulmaceae	40,70
120	<i>Vepris dainelli</i>	Rutaceae	47
51	<i>Verbascum sinaiticum</i>	Scrophulariaceae	44
116	<i>Vernonia galamensis</i>	Asteraceae	42
57	<i>Vernonia leopoldii</i>	Asteraceae	45,51,56
105	<i>Vernonia urticifolia</i>	Asteraceae	39,40,50,61
6	<i>Vernonia wollastouid</i>	Asteraceae	38,41
129	<i>Withania somnifera</i>	Solanaceae	39
87,91	<i>Ximenia americana</i>	Olacaceae	40,56,59,60,69

Appendix 6. Vegetation Data Collected From Mt. Alutu

Specimen code(s)	Scientific name of the specimen	Family	Quadrat
176	<i>Abutilon longicuspe</i>	Malvaceae	1
150	<i>Acacia abyssinica</i>	Fabaceae	1,2,3,5,17
181	<i>Acacia seyal</i>	Fabaceae	2,4,17,27
263	<i>Acokanthera schimperi</i>	Rubiaceae	6
207	<i>Actiniopteris dimorpha</i>	Actiniopteridaceae	8
218	<i>Andropogon sp.</i>	Poaceae	12,15,16,18,19,20,22,23,24,25,27,28,29,31,32
213,242,243,281	<i>Anthospermum herbaceum</i>	Rubiaceae	13,22,24
244	<i>Athrixia rosmarinifolia</i>	Asteraceae	23
154	<i>Balanites aegyptiaca</i>	Balanitaceae	1,2,6,17
167	<i>Bothriochloa insculpta</i>	Poaceae	1,3,4,5,6,7,8,9,10,11,13,16,18,19,21,22,23,25,27,28,29,30,32,33,34,35,36,37
179	<i>Calpurnia aurea</i>	Fabaceae	2,3
153	<i>Capparis fascicularis</i>	Capparidaceae	1,2,5,6,9
275	<i>Celtis africana</i>	Ulmaceae	3
168	<i>Chloris virgata</i>	Poaceae	1,2,5
222,223	<i>Clematis simensis</i>	Ranunculaceae	16
159	<i>Clutia abyssinica</i>	Euphorbiaceae	1,5,6,7,9,12,14,15,16,17
186	<i>Combretum adenogonium</i>	Combretaceae	4,8,11,12,13,4,15,16,18,19,23,27,29
257	<i>Conyza incana</i>	Asteraceae	29
251	<i>Crotalaria deserticola</i>	Fabaceae	37
180	<i>Crotalaria sacculata</i>	Fabaceae	2
178	<i>Croton dichogamus</i>	Euphorbiaceae	2,3,9
193	<i>Croton macrostachyus</i>	Euphorbiaceae	3,4
155	<i>Dichrostachys cinerea</i>	Fabaceae	1,3,5,8,9,12,17,19,21,28,29,35,37
171	<i>Digitaria nuda</i>	Poaceae	1,3,5,6,7,8,9,10,17
164	<i>Dodonaea angustifolia</i>	Sapindaceae	1,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,31,32,34,
230	<i>Echinops macrochaetus</i>	Asteraceae	7
261	<i>Englerina heckmanniana</i>	Loranthaceae	6
224	<i>Englerina woodfordioides</i>	Loranthaceae	1,5,16,
272	<i>Erianthemum dregei</i>	Loranthaceae	3

Contd.

187	<i>Erica arborea</i>	Ericaceae	4,5,7,8,9,10,13,14,15, 16,17,18,19,20,21,22, 23,24,25,26,27,28,29, 30,31,32,33,34,35,37,
229,239, 241	<i>Eriosema jurioniamum</i>	Fabaceae	16,34
280	<i>Euphorbia tirucali</i>	Euphorbiaceae	6
271	<i>Ficus ingens</i>	Moraceae	3,15
274	<i>Ficus sycomorus</i>	Moraceae	3
191	<i>Ficus vasta</i>	Moraceae	4
252	<i>Fimbristylis sp.</i>	Cyperaceae	37
277	<i>Flueggea virosa</i>	Euphorbiaceae	3
233	<i>Gardenia trifolia</i>	Rubiaceae	17
240	<i>Geranium arabicum</i>	Geraniaceae	22
276	<i>Grewia ferruginea</i>	Tiliaceae	3
260	<i>Harpachne schimperi</i>	Poaceae	18,28
170	<i>Heliotropium sp.</i>	Boraginaceae	1,2,3,4,17
182,206	<i>Heteromorpha trifoliata</i>	Apiaceae	4,5,7,8,9,10,13,14,15, 16,17,18,19,20,21,22, 23,24,25,26,27,28,29, 30,31,32,33,34,35,37
256	<i>Hyparrhenia anthistirioides</i>	Poaceae	18,28
214	<i>Hypericum revolutum</i>	Hypericaceae	16,19,22,24,25,26,28, 29
163	<i>Hypoestes forskaolli</i>	Acanthaceae	1,2,3,4,5,6
175	<i>Indigofera arabica</i>	Fabaceae	1
188	<i>Jasminum abyssincum</i>	Oleaceae	4,5,7,8,9,10,12,13,14, 15,16,17,18,19,20,21, 22,24,
174	<i>Kalanchoe laciniata</i>	Crassulaceae	1,2,3,6,27
247	<i>Kotschya recurvifolia</i>	Fabaceae	30,33,35,36,37
172	<i>Lactuca inermis</i>	Asteraceae	1,2,14
264	<i>Lansea schimperi</i>	Olacaceae	1,2,14,
160	<i>Leonotis sp.</i>	Lamiaceae	1,17
195	<i>Leucas abyssinica</i>	Lamiaceae	4
231	<i>Lippia adoensis</i>	Verbenaceae	17,30,35
215	<i>Maesa lanceolata</i>	Myrsinaceae	16,27,30
258	<i>Maytemis arbutifolia</i>	Celastraceae	15,20
152,205	<i>Maytemis senegalensis</i>	Celasteraceae	1,3,4,5,6,8,14,
192	<i>Melinis repens</i>	Poaceae	3,4,5,6,7,9,10,11,12, 13,14,15,16,17,27,30, 32,33,36,
248,249, 279	<i>Myrica salicifolia</i>	Myricaceae	33,36

Contd.

202	<i>Myrsine africana</i>	Myrsinaceae	5,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,27,28,29,30,31,32,33,
253	<i>Nuxia congesta</i>	Loganiaceae	31
234	<i>Ocimum gratissimum</i>	Lamiaceae	17
183	<i>Olea europaea</i>	Oleaceae	4,5,6,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,24,33,36
211	<i>Olinia rochetiana</i>	Oliniaceae	13,16,18,19,20,28,30,36
200	<i>Osyris quadripartita</i>	Santalaceae	5,7,8,9,10,11,14,16,18,19,20,21,23,24,28,31,35,36
184	<i>Ozoroa insignis</i>	Anacardiaceae	4,5,7,8,32,
245	<i>Picris abyssinica</i>	Asteraceae	28
203,259	<i>Protea gaguedi</i>	Protaceae	7,8,14,15,18,19,20,21,22,23,24,25,27,28,29,30,31,32,33,34,35,36,37,
204	<i>Psyrax schimperiana</i>	Fabaceae	7,9,13,14,15,
199	<i>Pteridium aquilinum</i>	Dennstaediaceae	5,14,16,21,22,23,24,25,26,28,31,32,35,36
232,265	<i>Rhoicissus tridentata</i>	Vitaceae	17
189	<i>Rhus abyssinica</i>	Anacardiaceae	4,5,7,8,9,16,17,29,30,32,33
227	<i>Rhus glutinosa</i>	Anacardiaceae	16
194	<i>Rhus natalensis</i>	Anacardiaceae	4,5,6,7,9,27
209	<i>Rumex nervosus</i>	Polygonaceae	10,18,25,37
220	<i>Rytigiyina neglecta</i>	Rubiaceae	16
208	<i>Sutureja punctata</i>	Lamiaceae	8,23
177	<i>Sida ovata</i>	Malvaceae	1
165	<i>Solanum indicum</i>	Solanaceae	1,2,3,6
225	<i>Smilax aspera</i>	Smilacaceae	16
185	<i>Syzygium guineense</i>	Myrtaceae	4,5,7,8,9,10,11,14,16,18,19,25,27
221	<i>Tephrosia interrupta</i>	Fabaceae	16,
250	<i>Tephrosia schweinfurthii</i>	Fabaceae	36
162	<i>Tragia cinerea</i>	Euphorbiaceae	1,2
217	<i>Triumpheta brachyceras</i>	Tiliaceae	15,16
219	<i>Vernonia abyssinica</i>	Asteraceae	16
156	<i>Ximenia americana</i>	Oleaceae	1,4,9,30
151	<i>Ziziphus mucronata</i>	Rhamnaceae	1,14

Appendix 7. Tukey's family error rate test between environmental variables and the community types. Mean \pm SE followed by different letter notations within each column indicate significant differences at $p < 0.05$. ns = not significant.

Community type	Altitude (m.a.s.l)	Slope degree	Slope aspect
1	1807 ^a ± 88.64	10.00 ^a ± 8.33	3.00 ^{ns} ± 1.16
2	1928 ^a ± 85.57	31.38 ^b ± 8.54	2.89 ^{ns} ± 0.79
3	2163 ^b ± 66.73	30.53 ^{cb} ± 9.25	2.80 ^{ns} ± 1.14
4	2272 ^{cb} ± 83.33	23.22 ^{abc} ± 10.79	3.03 ^{ns} ± 1.33
5	1850 ^a ± 70.71	2.5 ^a ± 3.54	3.00 ^{ns} ± 1.41
6	2025 ^a ± 247.49	16.0 ^{abc} ± 1.41	2.5 ^{ns} ± 0.00
7	2002 ^d ± 131.14	18.61 ^a ± 9.02	2.29 ^{ns} ± 1.29
8	2050 ^{abcd} ± 0.00	15.5 ^{abc} ± 7.80	4.00 ^{ns} ± 0.00

Appendix 8. Number of species recorded from each stand, Number of stands = 71, Number of species = 140.

Stand number	Number of species
1	22
2	14
3	20
4	21
5	23
6	16
7	18
8	19
9	19
10	12
11	9
12	11
13	14
14	16
15	18
16	27
17	20
18	16
19	15
20	12
21	11
22	13
23	11
24	12
25	12
26	6
27	15
28	13
29	10
30	13
31	10
32	10
33	10
34	8
35	9
36	11
37	9

Contd.

38	24
39	23
40	22
41	18
42	31
43	25
44	23
45	21
46	20
47	34
48	28
49	11
50	25
51	17
52	18
53	20
54	10
55	16
56	17
57	15
58	21
59	14
60	15
61	11
62	16
63	24
64	14
65	17
66	13
67	15
68	10
69	18
70	13
71	9

