VEGETATION SUCCESSION IN THE VOLCANIC REGION BETWEEN KULUMSA AND METAHARA

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By

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ABSTRACT

Six sites were studied in the Ethiopian Rift Valley in the Administrative Regions of Shoa and Arsi where volcanic eruptions had taken place at different times. The aim of the study was to determine vegetational succession on these volcanic rocks according to the chronosequence. The study was made from December 26, 1980 to February 6, 1982. Forty two stands were sampled (seven in each site) and the presence of 172 species in the stands was recorded.

Computer analysis of the raw data using Normal Association Analysis was made at the Central Statistical Office (C.S.O) in Addis Ababa and using Indicator species Analysis (I.S.A.) at the Ethiopian Road Authority (E.R.A).

Indicator species Analysis divided the vegetation in the study areas into groups according to the chronosequence while that using Normal Association Analysis did not.

The groupings obtained from the Normal Association Analysis and the Indicator species Analysis were statistically tested for significant contrasts.

Wolenchiti (third in chronosequence) was found to have the highest number of grass and herb species. The successional trend for all species of plants showed an increase from the first upto the third age levels and a decrease in the fourth and fifth age levels except for the shrub species where the fifth age level showed the maximum number.

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1. INTRODUCTION

It is appropriate to give a brief introduction on the subject of succession because this study involves the investigation of vegetation succession on basaltic lava flows.

Succession is vegetational development by the reaction of the vegetation on the environment followed by the appearance of fresh species (Kershaw, 1975).

Closely similar substrates with different known dates of formation provide a very useful basis in succession studies. These include differently aged lava flows, volcanic ash substrates, differently aged land scars and sand dunes (Muller-Dombois and Ellenberg, 1974).

Clements (1916) as cited by Kershaw (1975) divides succession into primary succession initiated on a bare area and secondary succession which is a result of major environmental disturbance disrupting a previously initiated succession.

According to Weaver and Clements (1938) permanent quadrates can be observed continuously for successional studies. Successional studies can also consist of comparison of present vegetation growing on similar substrates of different ages and the present study is of the later type.

The Ethiopian Rift Valley System has been affected by volcanism since Pliocene times causing fissure eruptions and growth of individual volcanoes while the neighbouring plateau was affected since Eocene times (Di. Paola, 1972).

The study areas were chosen in a part of the Ethiopian Rift Valley System inorder to obtain substrates affected by lava flows at different times which can provide a basis for studying vegetation succession.

An attempt is made in this study to establish successional trends in volcanic regions of basaltic origin of different ages and related this to various environmental factors. The raw data was made available to meaningful interpretation using Normal Association Analysis and Indicator Species Analysis.

This study could be important for keeping a record of plant species present in the study areas and for the purposes of conservation.

2. LITERATURE REVIEW

2.1 Geology

The study areas are located in the Ethiopian Rift Valley within the Administrative Regions of Shoa and Arsi of Ethiopia. Therefore, it is appropriate to give a brief account of the Ethiopian Rift Valley system.

A Rift Valley can be defined as an elongated sunken area with a characteristic width of 30 - 60 kms which has descended between parallel faults (McConnel, 1967).

However, Mohr (1962, 1967) reported that the width of the Ethiopian Rift Valley is 90 kms at L.Shala, 80 kms at L.Awasa and 60 - 70 kms at L.Abaya and the average distance separating the Eastern and Western boundry faults is about 80 kms.

The Ethiopian Rift Valley system is a part of a system of downfaulted troughs passing through East Africa, the Horn of Africa, the Red Sea then Israel, Jordan and Syria and is 5,000 kms in a North - South direction.

The East African part of this downfaulted troughs extnds 4,000 kms South - Southwest from the junction of the Red Sea and Gulf of Aden to the Zambezi River (McConnel, 1972; Mohr, 1962).

The most typically developed part of the East African Rift System is known as the Ethiopian Rift and extends from L. Chamo in the South to Afar in the North (Mohr, 1963).

The formation of the rift system, is believed to have been during the tertiary period, which was a time of great activity and change for the Horn of Africa. During this time, the whole region was uplifted in a dome formation including the whole of present Ethiopia. As the uplifting continued, there was cracking and the centre of the dome dropped down to form the Rift Valley System (Last, 1963).

McConnel (1972) reported that the uplift of the Arabo-Ethiopian swell immediately preceded the rifting. He explained this further as follows:-

> The rift system can best
> be explained as the result
> of fructuring of the lithosphere
> under tension from an uplifting
> sub - crust, the fructured
> blocks being free to move
> under isostatic readjustment
> forces.

According to Di. Paola (1972) volcanism has affected the neighbouring plateau since Eocene times and the rift itself since Pliocene causing fissure eruptions and growth of individual volcanoes. He reported further that the triple junction at the Afar depression where sea - floor spreading is taking place makes the Ethiopian Rift system important.

Kazmin and Seife (1978) have given a report of two volcanic activities (which are a part of this study) as follows:-

Bofa basalts erupted more than three million years ago most probably in the Pliocene. These basalts are found in the vicinity of Bofa village overlapping with ignimbrites and are mostly aphyric, locally vesicular and very fresh. They were produced from fissure eruptions caused by the tectonic movements. Tulu Moye is one of the main volcanic centers in the Wonji fault belt and the early eruptions produced strongly porphyritic plagioclase basalts.

2.2 Ecological Methods

2.2.1 Sampling

In ecological studies, sampling is necessary because studies of the whole vegetation segment of an area consumes too much time; therefore ecologists use different sampling techniques to obtain the necessary information (Mueller-Dombois and Ellenberg, 1974).

According to Oosting (1956) observation and reconnaissance survey are very important in determining where and how to sample a community. Mueller-Dombois and Ellenberg (1974) support the above statement and recommend a thorough survey and familiarization before sampling.

Many ecologists have examined sampling techniques and what follows is a summary of the observations made by Mueller-Dombois and Ellenberg (1974) and Kershaw (1975).

A sample stand should have the following requirements:

1. It should be large enough to represent the species in a community.
2. Uniformity within the stand and plant cover should be as homogenous as possible.
3. The type of community affects the minimal area and they suggest a minimal area of 200 - 500 sq.m.
4. The position of each quadrat should be independent of any prominent feature of the area.

2.2.2 Gradient Analysis

Goff and Cottam (1967) reported that gradient analysis by means of species indices and synthetic values provides a very fruitful approach to ecological investigation. Values for several species occuring together in a given stand can be combined to give a synthetic index for the stands as a whole.

According to Whittaker (1967) direct gradient analysis is the approach from environment to floristic analysis. Indirect gradient analysis is the approach through patterns formed by the vegetation itself.

Gauch (1982) has given a detailed explanation of direct gradient analysis as an important technique in ecology and a summary of what he discussed follows.

Direct gradient analysis is used to study the distribution of species along recognized easily measured environmental gradients and is quite different from classification and ordination in implementation because it involves simple graphing procedures as opposed to the sophisticated mathematics and computers needed for classification and ordination. Direct gradient analysis is used to show the distribution of organisms along gradients of major environmental factors while classification and ordination begin with the analysis of community data and later use environmental data for interpretation. This technique contributes substantially to the foundation upon which classification and ordination stand.

2.2.3 Classification

Classification accepts the concept of vegetation as composed of discrete communities which are discontinuous or markedly heterogenous. The individuals (sites) are arranged in groups. The classification method of vegetation description is mainly qualitative and species presence and absence is considered more important than minor variations in quantity (Lambert and Dale, 1964).

Williams, Lambert and Lance (1966), Lambert and Dale (1964), Gauch and Whittaker (1981) and Hill, Bunce and Shaw (1975) have discussed various types of classifications.

According to these authors, if the prime requirement is to produce vegetational units which can be used for mapping or description, classificatory methods are applicable. Classification could be hierarchial or reticulate, sub-divisive or agglomerative, and monothetic or polythetic.

A hierarchial classification has groups obtained at many levels, ranked in importance, and may not be dichotomous. Hierarchial methods are better known, less cumbersome and more widely used in ecological work than direct cluster techniques.

Reticulate or non-hierarchial methods deal with inter-group distances irrespective of the method of group extraction. When reticulately formed groups are split into sub-groups, the classification becomes semi-hierarchial.

A sub-divisive technique concentrates on differences and starting with a whole population of stands, divides into successively small groups. The population is progressively divided into groups of diminishing size.

A monothetic method uses the presence and absence of a specified attribute to define groups. A polythetic method uses a combination of attributes inorder to define the groups.

Mueller-Dombois and Ellenberg (1974), Kershaw (1975), McIntosh (1962) and Williams and Lambert (1960) have discussed Normal Association Analysis as a method of classification. The following is a summary of what they discussed.

Normal Association Analysis is a hierarchial, divisive and monothetic method. Normal Association Analysis uses indices of association between every pair of species. The index of association used by the authors is chi-square.

The 2 X 2 contingency table is used to calculate chi-square. Normal Association Analysis uses some correlation coefficient (eg. V = point correlation coefficient) to measure Co - occurrance of any pair of species and then chi-square is used to measure significance in the correlation. The chi-square shows whether the difference between the observed and expected number of quadrats in each category is significant or due to chance.

The 2 X 2 contingency table is constructed as follows:-

		Species A		
		+	-	
Species B	+	a	b	a + b
	-	c	d	c + d
		a+c	b+d	n = a+b+c+d

Where a = observed number of quadrats containing both species A and B

b = Observed number of quadrats containing only species B.

d = observed number of quadrats without either of the two species.

The formula for chi-square is:-

$$\text{chi-square} = \frac{(ad - bc)^2}{(a + b)\ (c + d)\ (a + c)\ (b + d)}$$

The chi-square formula with Yate's correction:-

$$\text{chi-square} = \frac{(ad - bc - n/2)^2 \ X \ n}{(a + b)\ (c + d)\ (a + c)\ (b + d)}$$

In Normal Association Analysis, 2 X 2 contingency tables are established for all the species though those below 5% and above 95% occurrence in the sample quadrats may be left out. The chi-square values are summed up for each species and the species with the highest chi-square is used to separate the quadrats into two groups, i.e. those that have it and those that do not.

Then, fresh contingency tables are established for each of the two groups of quadrats thus established and the process repeated.

Inverse Association Analysis is a system of classification of the species in terms of the stands in which they occur (Lambert and Dale, 1964). Here, the groups of species occuping roughly the same range of stands will be extracted. The member species of each species group will have certain ecological properties in common. In Normal Association Analysis, quadrats are classified by the presence or absence of species whereas in Inverse Association Analysis, species are classified by the manipulation of quadrats in which they occur.

A generalization of Association Analysis which retains the good features and avoids the high misclassification rate, is known as Indicator Species Analysis. In indicator species analysis, five indicator species are chosen and the method is based on reciprocal averaging. Indicator species analysis is a divisive polythetic method of numerical classification which can be used to large sets of qualitative or quantitative data (Hill, Bunce and Shaw, 1975).

2.2.4 Ordination

Ordination accepts the idea of vegetation as being continuous (continuum concept).

The individuals are arranged on axes, with their properties determining their positions, and the results are a set of new axes on which the sites can be replotted in a convenient form (Lambert and Dale, 1964).

According to Gauch (1982) the result of ordination is the arrangement of species and samples in a low - dimensional space such that similar entities are close by and dissimilar entities far apart.

Mueller - Dombois and Ellenberg (1974) described ordination as a technique which aims at description through the arrangement of sample stands in order of similarity or environmental gradients while Risser and Rice (1971) defined ordination as a series of techniques which graphically represent similarity between stands, species and environmental variables.

Ecologists use varied ordination techniques such as principal components analysis, reciprocal averaging and coefficient of similarity ordination.

Principal Components Analysis (PCA)

Gauch (1982) explained how the name principal components analysis was coined as follows:-

Various variables are termed components and have different degrees of importance, but interest is attached to the major or principal component and hence the name principal component analysis.

According to Pielou (1977) as quoted by Gauch (1982) PCA ensures efficient projection of points in a multi-dimensional spaces into fewer dimensions and the points are arranged in such a way that they will have the least possible distortion. Principal components Analysis is a very common type of ordination which uses all information about species and is a very successful technique applied to data ordination.

Reciprocal Averaging

Hill (1973) has defined reciprocal averaging as an ordination method which is a combination of Whittaker's gradient analysis and the method of successive approximation. It is called reciprocal averaging because the species scores are average of the stand scores and reciprocally, the stand scores are averages of the species scores. It is similar to principal components analysis but it is more suitable for displaying strong floristic gradients.

Coefficient of Similarity Ordination

The coefficient of similarity ordination (Bray and Curtis method) is described by West (1966) as follows:-

Community studies yield a natural division of the landscape, its biological productivity and management problems. The coefficient of similarity between stands has the formula:-

$$C = \frac{2W}{A + B} \times 100$$

Where C = coefficient of similarity

A = sum of all physical and chemical measurements for one stand

B = sum of all physical and chemical measurements for another stand.

W = sum of the lower values for each species which the two stands have in common.

Gauch and Whittaker (1972) after analyzing eight ordination techniques reported that the Bray - Curtis ordination using Sorensen's coefficient of community was found to be the best and principal components analysis the worst.

In conclusion, in ecological investigations, classified units can be ordinated, and ordinated units classified. Which method to use depends on the investigator irrespective of the nature of the vegetation (Lambert and Dale, 1964).

Stands sampled for classification can be subjected to ordination. But, stands sampled for ordination can be classified only when they are floristically complete enough (Mueller - Dombois and Ellenberg, 1974).

2.3 Succession

Succession can be defined as a pattern of changes in the specific composition of a community after a radical disturbance or after the opening of a new patch in the physical environment for colonization by plants and animals (Horn,1974).

Weaver and Clements (1938) defined succession as the development of vegetation on the same areas as it becomes successively occupied by different plant communities.

Successional studies can consist of continuous observations on permanent quadrats or comparison of present vegetation growing on similar substrates of different ages. The present study is of the later type.

Successional studies are of various types such as succession on rock outcrops, succession on sand dunes, Glacier succession, succession after fire, succession on abandoned fields, and succession on water bodies.

Veno (1976) made studies on 20 year old permanent quadrats located in fire plant communities to determine successional changes. The area was protected from fire. He found out that all quadrats increased in species composition and the trend was towards mesophytic communities.

Succession studies on granite outcrop surfaces have shown that plant biomass and vertical stratification increase throughout succession. Lichens, annuals and eventually perennial species invade as succession progresses (Shure and Ragsdale, 1977).

Mudflows and avalanches extending over 1500 years presented a nearly ideal successional series. Nine conifers were found in these substrates showing that conifers are capable of successional invasion of raw substrates. Added refinement of the accumulated materials makes the development much more rapid than it would be in the case of the unfragmented rock (Heath, 1967).

Chadwick and Dalke (1965) and Kumler (1969) have studied succession on sand dunes which can be summarized as follows:

The presence of dense shrub stands on dunes now topographically sheltered by the wind, but not on migratory dunes, indicates that establishment of a species on sand depends on relative site stability rather than on soil nutrient buildup caused by previous vegetation. As plants increase in number and size, the sand becomes stabilized, and there are associated changes in the micro-environment and rapid changes in plant associations. Successional communities vary from small herbacious species in wind swept, moving sand through shrubs in more stabilized sand. The authors further reported that distinct communities in their study areas suggest a successional pattern.

The postglacial vegetation of the Ruwenzori mountain in equatorial Africa was studied by Viereck and Livingston (1966) and they found that there is a shift from relatively open vegetation to closed climax forests. There was a gradual shift from dry to moist climate.

Chaparral is a special type of scrub vegetation which consists of shrubs which tend to grow in dense stands. Succession after fire was studied in the chaparral of Southern California and the rate of change was found to be influenced most by aspect while percentage of the slope was of least importance (Hans, 1967).

Hans and Jones (1967) found that vegetation after fire was altered in plant numbers within species and also in species composition.

Bazzaz (1968) studied succession on abandoned fields in the Shawnee Hills, Southern Illinois. The abandoned fields were of eight different ages ranging from 1 - 40 years. The first year was occupied by annuals and the field was successively invaded by perennial herbs, shrubs and finally trees.

Marrs (1981) studied ecosystem development on naturally colonized china clay wastes and reported that new and developing ecosystems have a lower proportion of total nutrients than in most well developed ecosystems.

Secondary succession may be studied directly by observing the changes on an area over a long period or by comparisons of fallows of different ages on similar soil types in a homogenous zone.

Game, Carrel and Hotrabhavandra (1982) studied six sites on abandoned surface coal mines. They found that they were rapidly colonized by plants which grew to form patches. The patches were found to grow at a uniform rate while new patches were also being formed. As the patches grew, they become less circular and finally there was a fusion of the patches.

It is believed that all successional developments lead to a relatively stable state known as a climax.

A climax is a pattern of species abundances which while locally constant, varies from place to place in a continuous fashion. In a succession that is not subject to extensive and chronic disturbance, the diversity of the climax must be lower than that of some preceeding stage (Horn, 1974).

Within a region, the same final or climax stage results from a series of successive stages whether they start in open water, on solid rock or in denuded land. Therefore, a climatic region has one potential climax, the most mesophytic community that the climate can support (Weaver and Clements, 1938).

The above description of a single climax system for all forms of successional development is known as the monoclimax theory or the climatic climax.

Hans (1971) defined climax vegetation as a stable, self-perpetuating plant community which terminates a series of floristic changes. Climax can be applied to every relatively stable, self-perpetuating community that terminates succession and does not imply a connection with climate. Therefore, edaphic, topographic, and salt spray climaxes can be recognized. This is known as the polyclimax theory.

Comparing the monoclimax and polyclimax theory, Kershaw (1975) suggested that the polyclimax theory is more realistic because climate is not stable and other environmental factors influence the final vegetation of an area in addition to climate.

3. STUDY AREAS

The study areas are located in Shoa and Arsi Administrative Regions of Ethiopia at longitudinal ranges of $39^{o}10'$E to 39^{o} $50'$E and latitudinal ranges of $8^{o}3'$N to $8^{o}55'$N within the Ethiopian Rift Valley.

The choice of the study areas was made in such a way that factors like slope, elevation and aspect except for the age of the basaltic lava flows was as uniform as possible.

A description of the study areas is given as follows with the areas of study arranged according to their chrono-sequence starting from the youngest to the oldest basaltic lava flows.

According to this chronosequence, the study areas were:-

a) Metahara c) Wolenchiti e) Bofa

b) Sodere d) Kulumsa f) Balchi

(The map of the study areas is shown in Fig.1).

3.1 Metahara

This study area is composed of recent aphyric basalts (basic soria) (Kazmin and Seife, 1978).

The volcanic eruption is said to have been a viscous flow from a small cone on the foothills of Fentale crater mountain overlooking L. Beseka and to have taken place about 200 years ago (Giday W/Gabriel, personal communication).

This site is 190 kms from Addis Ababa along the highway to Awash, at a longitude of $39^{o}50'$E and a latitude of $8^{o}54'$N, with an altitude of 1080 meters above sea level. It has an aspect of N10^{O}E and a slope of 0^{O} as measured from the top surface of the boulders.

Since this area consists of basalts of very recent volcanic eruption, there is very little vegetation. There is no agricultural practice around this study area except for a little nomadic pastoralism on older welded tuff around the town of Metahara, which is 2 kms away.

3.2 Sodere

This study area is made up of recent aphyric basalts which are in the geological period ranging from the beginning of Pleistocene to recent (Holocene) (Kazmin and Seife, 1978).

This study area is 129 kms from Addis Ababa about 9 kms east from Awash Melkasa on the Nazreth-Assela road, at a longitude of 39^{O}21'E and a latitude of 8^{O}24'N.

The altitude of the study area ranges from 1400 meters to 1570 meters above sea level and the slope from 5^{O} to 15^{O}; the aspect is northerly.
There is no agricultural activity in this study area except for a state farm about 5 kms away.

3.3 Wolenchiti

This study area consists of Pleistocene subrecent basalts, the rocks being vesicular basalts, with very coarse plagioclase and olivine crystals which are slightly weathered at the top (Kazmin and Seife, 1978).

The Pleistocene subrecent period ranges from 7 million years to recent (Foster, 1979) but according to Kazmin and

Seife (1978) the lower age limit of the basalts is 2.8 to 2.5 million years and the authors quote Mohr (1973) as reporting an age of 3.5 - 0.9 million years.

This study area is 175 kms from Addis Ababa along the Addis Ababa Awash highway at a longitude of 39°30'E, a latitude of 8°40'N with an altitude of the area ranging from 1300 meters to 1320 meters above sea level and the aspect is essentially northerly.

Agricultural practice stops only a few kilometers from the town of Wolenchiti on the way to Metahara, at an altitude of 1460 meters at about a distance of 130 kms from Addis Ababa along the Metahara road at the point where the Pleistocene subrecent rocks are encountered.

There are no settlements on this study area except for temporary shelters along the sides of the highway erected for the sale of charcoal prepared from the surrounding vegetation. But, now this is being stopped by the Ministry of Agriculture.

3.4 Kulumsa

This area consists of porphyritic feldspars of Tulu Moye. Tulu Moye is along the Wonji fault belt and is one of the main volcanic centres in the Nazreth region where eruption took place in the upper middle Pleistocene (Kazmin and Seife, 1978). The upper middle Pleistocene is a geological period which ranges from 7 million years to recent (Foster, 1979).

The study area is 12 kms away from Kulumsa along the road to Ugolcha, a village in the vicinity of L.Zwai.

Kulumsa is a small town along the Nazreth - Assela highway which is found 15 kms before reaching the town of Assela.

This area is located at a longitude of 39°10'E and a latitude of 8°3'N.

The altitude of the area is between 1900 meters and 1910 meters above sea level; the aspect being mostly northerly, with the slope ranging from 5° to 15°.

There is some crop cultivation around scattered hamlets in the vicinity of the study area.

3.5 Bofa

This study area consists of Bofa basalts from the upper Pliocene and Morbidelli et al (1975) as reported by Kazmin and Seife (1978) has reported that the age of overlaying Bofa basalts is most probably older than 3 million years.

The upper Pliocene is a period in the geological era ranging from 7 million years to recent (Foster, 1979).

This study area is in the vicinity of Bofa village, which is 11 kms away from Sodere hot springs, at a longitude of 39°27'E and a latitude of 8°27'N. The altitude of the area ranges from 1900 to 1910 meters above sea level; their aspect is northerly and their slope ranges from 5°to 10°.

There are two state farms a few kilometers from Bofa village and cattle graze near the study area.

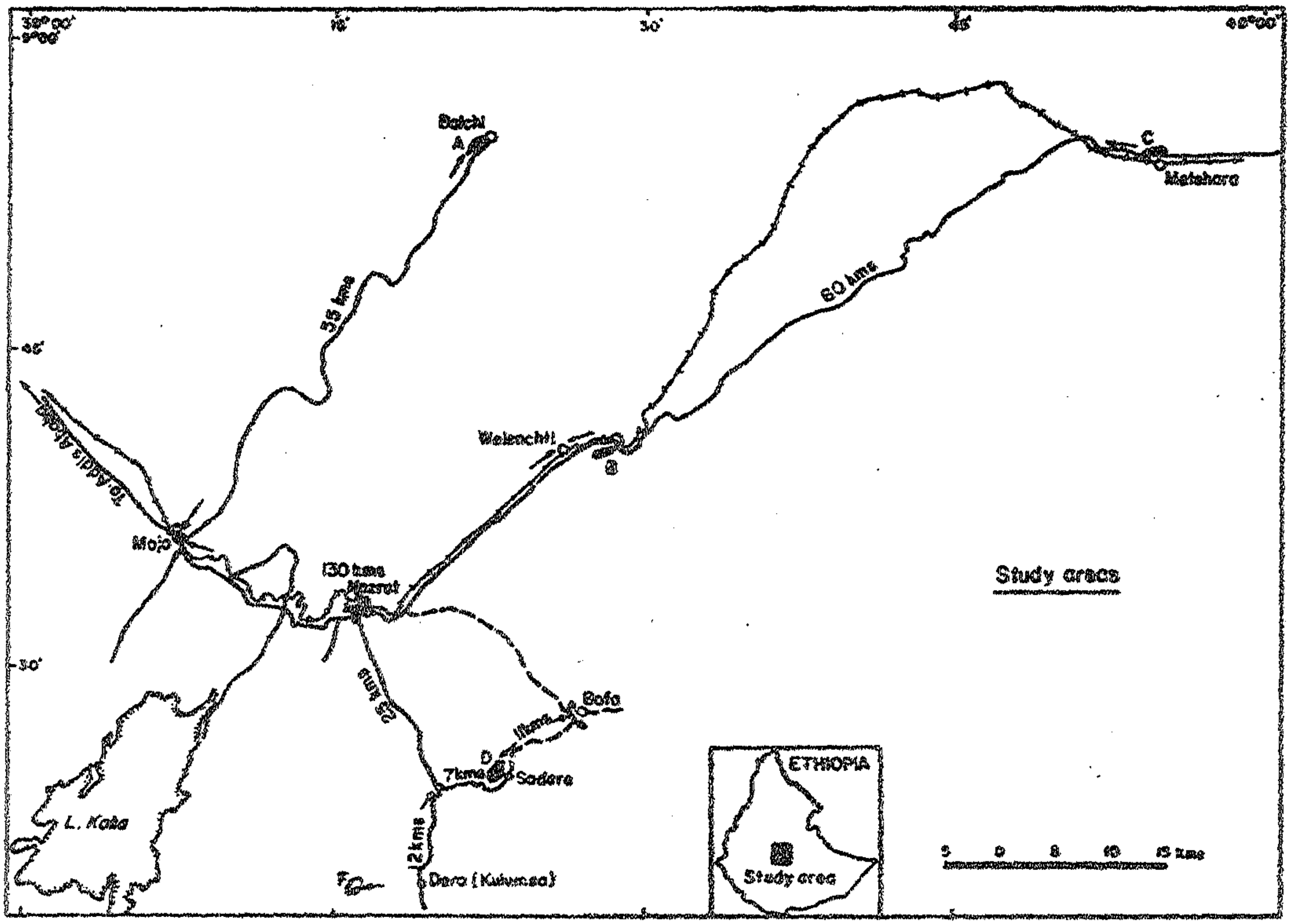
3.6 Balchi

The study area consists of Alage basalts from the upper Miocene to Pleistocene (Kazmin and Seife, 1978). This period is between 26 million years and 7 million years (Foster, 1979).

The study area is 55 kms N.E. of Modjo along a branch of the Kesem gorge downhill from the small town of Balchi; at a longitude of 39°22'E and a latitude of 8°55'N. The altitude of the stands ranges from 1890 meters to 1940 meters above sea level with aspect being northerly and the slope between 5° to 15°.

There is virtually no human interference in the study area except at the upper part of the gorge just below the town of Balchi where there is some grazing on the Anchar basalts.

Fig. 1 A map of the study area



4. MATERIALS AND METHODS

An initial survey of the study areas was made from December 28, 1980 and from February 27 to February 29,1981.

Then the geological map of the area (Nazreth sheet) compiled by Kazmin and Seife (1978) was referred to and a geological survey was made from March 14 to March 17,1981 to determine the exact location of the stands within the study area.

The Quadrat Sampling Method was used and seven (20mX20m) stands were chosen in each study area. The total number of stands sampled in the study areas was thus 42.

Vegetation data were collected from October 13 to October 22, 1981 and soil samples obtained (from the vegetation stands sampled) from February 1 to February 6, 1982.

Some of the plants were identified in the field and those that could not be identified were brought to the National Harbarium for identification.

Soil samples were collected from the surface up to the depth of 40 cm as it was not possible to auger beyond this depth because the underlying rock was reached.

The slope and aspect of stands was determined with a Brunton compass and altitude with an Everest altimeter manufactured by Thommen of Switzerland.

The percentage of area occupied by exposed rock was also visually estimated for each stand in the study areas.

Soil samples collected in polythene bags were labelled with a felt - pen and a small identification tag included in each. The polythene bags were brought to the laboratory where the soil samples were air-dried and their physical and chemical properties determined.

The p^H and electrical conductivity of the soil samples were determined using a portable Beckman chem-Mate p^H meter and a portable Harris conductivity meter from 1:1 soil - distilled water mixtures (20 g of soil in 20 c.c. distilled water) prepared from each sample collected.

The dry and wet colours of each soil sample were obtained by comparison with the 1975 edition of the Munsell soil colour chart.

To determine the cation content of the soil samples, 5g of each soil sample collected was weighed and leached with one normal ammonium acetate solution.

The sodium and potassium of each soil leachate was then determined with a Klina flame photometer manufactured by Beckman Instrument Inc. of California.

5. RESULTS

The data were analyzed by computer using Normal Association Analysis at the Central Statistical Office (C.S.O.) and using Indicator Species Analysis at the Ethiopian Road Authority (E.R.A.) in Addis Ababa.

5.1 Normal Association Analysis

The sub-division for the normal association analysis was stopped when the highest chi-square value became less than 3.84 ($p=0.05$). Plants with less than 5% and greater than 95% occurrence were not used for classification. Thus, of the 172 species recorded in the study areas, only 55 were used for classification.

The computer print out produced 8 groups (A - H) and 14 stands were put together as a ninth group (I) with a chi-square value of less than 3.84 (Fig.2).

However, since 4 of the groups (E,F,G and H) were too fragmentary i.e. they have small sample numbers which would make meaningful comparison difficult, recombinations were made to obtain only 4 groups (A,B,C and D) as shown in the dendrogram in Fig.3. (The plant numbers written in figures 2 and 3 refer to the plant names listed in appendix I).

Group A is characterized by the presence of *Heliotropium aegypticum* and contains 9 stands which were obtained by combining two groups containing 3 and 6 stands respectively.

Group B consists of 6 stands and is characterized by the absence of *Heliotropium aegypticum* and the presence of *Acacia senegal*.

Group C consists of 5 stands and is characterized by the absence of Acacia senegal and the presence of Indigofera ambelacensis.

Group D consists of 22 stands and is characterized by the absence of Indigofera ambelacensis. (The stands present in each group are shown in table 1 and the species present in each stand are shown in appendix J).

One way analysis of variance was applied to calculate the F value to see if there was significant difference in the environmental parameters among the 4 vegetation groups and only chroma was found to be significantly different i.e. above the critical value of 2.85 at $p = 0.05$ (Table 3).

Duncan's multiple range test was applied to the parameter chroma and vegetation group C showed the highest mean, vegetation groups A and D medium and vegetation B had the lowest mean.

N.B. - the environmental parameters are shown in appendices A-H.

Ranking for age was not possible for the vegetation groups in association analysis. Therefore, the ranking for each environmental parameter was compared with the ranking of every other environmental parameter and 55 pair combinations were considered to obtain Spearman's rank correlation coefficient.

The frequency distribution of the Spearman's rank correlation coefficients of the environmental parameters are shown in tables 5 and 6.

Five pair combinations were found to be strong positive, 15 positive, 10 negative and 6 strong negative.

5.2 Indicator Species Analysis

All the 172 species recorded in the study areas were used for the indicator species analysis. However, the rare species did not turn up to be indicator species and were not responsible for the sub-division of the stands in the groups.

The dendrogram prepared from the computer print out (Fig. 4) showed 15 groups at the end of the sub-division.

It was necessary to make recombinations because the groups were very fragmentary as the following stand numbers for each group shows. Group A 3 stands, Group B 4 stands, Group C 1 stand, Group D 4 stands, Group E 1 stand, Group F 3 stands, Group G 1 stand, Group H 4 stands, Group I 3 stands, Group J 2 stands, Group K 9 stands, Group L 1 stand, Group M 1 stand, Group N 4 stands and Group O 1 stand.

The recombinations showed 5 groups as is shown in the dendrogram in Figure 5.

Group A contains 7 stands which are located in the Metahara area which is made up of the youngest basaltic lava flows. The indicator species responsible for separating this group from the other groups was Rhynchelytrum sp.

Group B is characterized by containing stands separated from the remaining stands by Kalanchoe marmorata and has 6 stands.

Group C is characterized by the presence of the indicator species "crustose lichen" (orange) and consists of 7 stands.

Group D is characterized by the presence of the indicator species Delphinium dasycaulon and consists of 8 stands.

Group E is characterized by the presence of the indicator species Cissus quadriangularis and Zizphus spina-christi and consists of 14 stands. (The stands present in each group are shown in table 2 and the species present in each stand are shown in appendix J).

One way analysis of variance was applied to calculate the F value to see if there was significant difference in the environmental parameters among all the vegetation groups except for group A. Group A has not been compared with the other groups because the area in which it is located is virtually all rock and it was difficult to get soil samples.

There were only 3 significantly different parameters namely chroma, value and potassium i.e. above the critical value of 2.85 at $P = 0.05$ (Table 4).

Duncan's multiple range test was applied to the parameters which were found to be significant.

For the parameters chroma and value the vegetation group E showed high mean while vegetation groups B,C and D showed low means. For the parameter potassium, vegetation groups B and E showed high means while vegetation groups C and D showed low means.

The ranking for age of the vegetation groups was compared with the ranking for 11 environmental parameters and 11 pair combinations were considered to obtain Spearman's rank correlation coefficient.

The frequency distribution of the Spearman's rank correlation coefficients of the rnvironmental parameters are shown in tables 5 and 6.

Three of the parameters showed strong positive, two positive, three negative and two strong negative relations with the chronosequence.

Table 1. Vegetation groups and stands present in them (Association Analysis)

Vegetation groups	Stands Present in them
Group A	3, 5, 8, 13, 16, 17, 21, 33, 37.
Group B	12, 14, 19, 22, 38, 41.
Group C	4, 6, 10, 23, 27.
Group D	1, 2, 7, 9, 11, 15, 18, 20, 24, 25, 26, 28, 29, 30, 31, 32, 34, 35, 36, 39, 40, 42.

Table 2. Vegetation groups and stands present in them (Indicator Species Analysis).

Vegetation groups	Stands present in them
Group A	1, 2, 3, 4, 5, 6, 7.
Group B	36, 37, 38, 39, 40, 42.
Group C	15, 16, 17, 18, 19, 20, 21,
Group D	22, 23, 24, 25, 26, 27, 28, 41.
Group E	8, 9, 10, 11, 12, 13, 14, 29, 30, 31, 32, 33, 34, 35.

Table 3. The total, explained and unexplained sum of squares and F values for the environmental parameters (Association Analysis)

Environmental parameter	Total S.S	E	U	F
Slope	791.07	18.39	772.68	0.30
% exposed rock	33400	4370.08	29029.92	1.91
Hue	167.14	3.45	163.69	0.22
Chroma	52.69	41.12	11.57	37.05
Value	50.29	2.13	48.16	0.46
Conductivity	2890.66	319.05	2571.61	1.28
pH	6.07	0.23	5.84	0.42
Sodium	7017.14	332.30	6684.84	0.51
Potassium	102418.97	6328.88	96090.09	0.68
Altitude	3863876.60	296278.62	3567598	1.05
Soil depth	2274.29	386.94	1887.35	2.14

N.B - S.S = Sum of squares,

E = Explained,

U = Unexplained.

Table 4. The total explained and unexplained sum of squares and F values for the environmental parameters (Indicator Species Analysis)

Environmental parameter	Total S.S	E	U	F
Slope	404.29	56.23	348.06	1.67
% exposed rock	21247.14	2740	18507.14	1.53
Hue	156.69	16.83	139.86	1.24
Chroma	52.69	11.79	40.9	2.98
Value	50.29	15	35.29	4.39
Conductivity	2890.79	19.88	2870.91	0.07
pH	53.39	1.41	51.99	0.28
Sodium	7017.14	174.88	6842.26	0.26
Potassium	103735.6	33960.74	69774.8	5.03
Altitude	15460947	2250374	13210573	1.76
Soil depth	9574.29	176.67	9397.62	0.19

N.B - The explained and unexplained degrees of freedom for each parameter in tables 3 and 4 are 3 and 31 respectively.

Table 5. Spearman's rank correlation Coefficient classified by frequency distribution

Range	A	B
-1.0 ______ -0.81	2	1
-0.8 ______ -0.61	4	1
-0.6 ______ -0.41	2	0
-0.4 ______ -0.21	8	2
-0.2 ______ -0.01	0	1
0 ______ +0.19	0	0
+0.2 ______ +0.39	2	0
+0.4 ______ +0.59	13	2
+0.6 ______ +0.79	0	0
+0.8 ______ +1.0	5	3

Table 6. <u>Spearman's rank correlation Coefficient classified into groups</u>

	A	B
Strong positive	5	3
Positive	15	2
Zero	-	-
Negative	14	3
Strong negative	6	2

<u>Remarks on tables 5 and 6</u>

A.

Strong positive	=	+0.6 ______ +1.0
Positive	=	+0.59 _____ 0
Negative	=	-0.5 ______ 0
Strong negative	=	-0.6 ______ -1.0

B. The letter A stands for Association Analysis and B stands for Indicator Species Analysis.

C. Spearman's rank correlation coefficient was not applied for 19 pairs in group A and one pair in group B because there was a repetition of rank in some pair members.

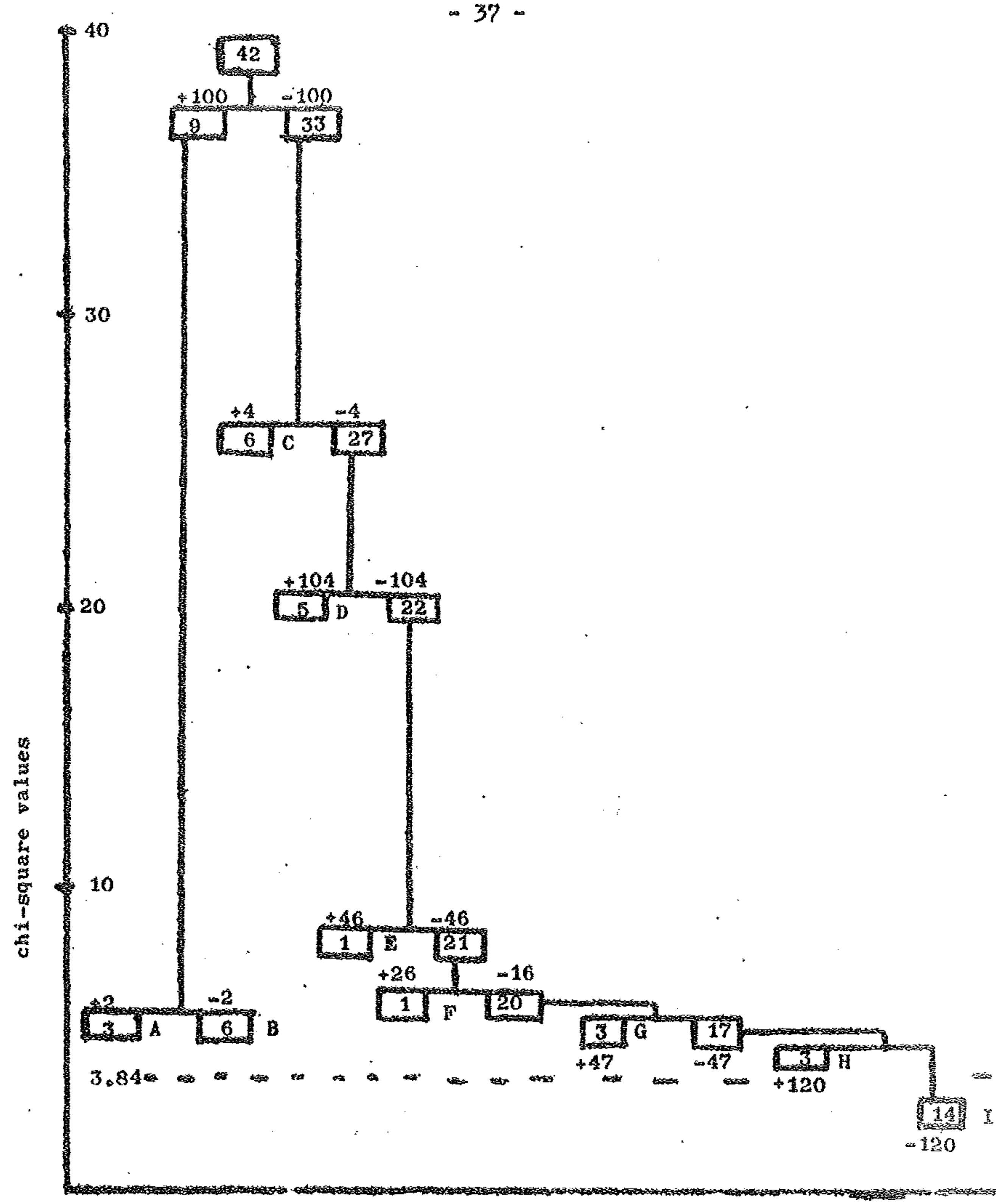


Fig. 2 - Dendrogram - showing the vegetation types
(Normal Association Analysis)

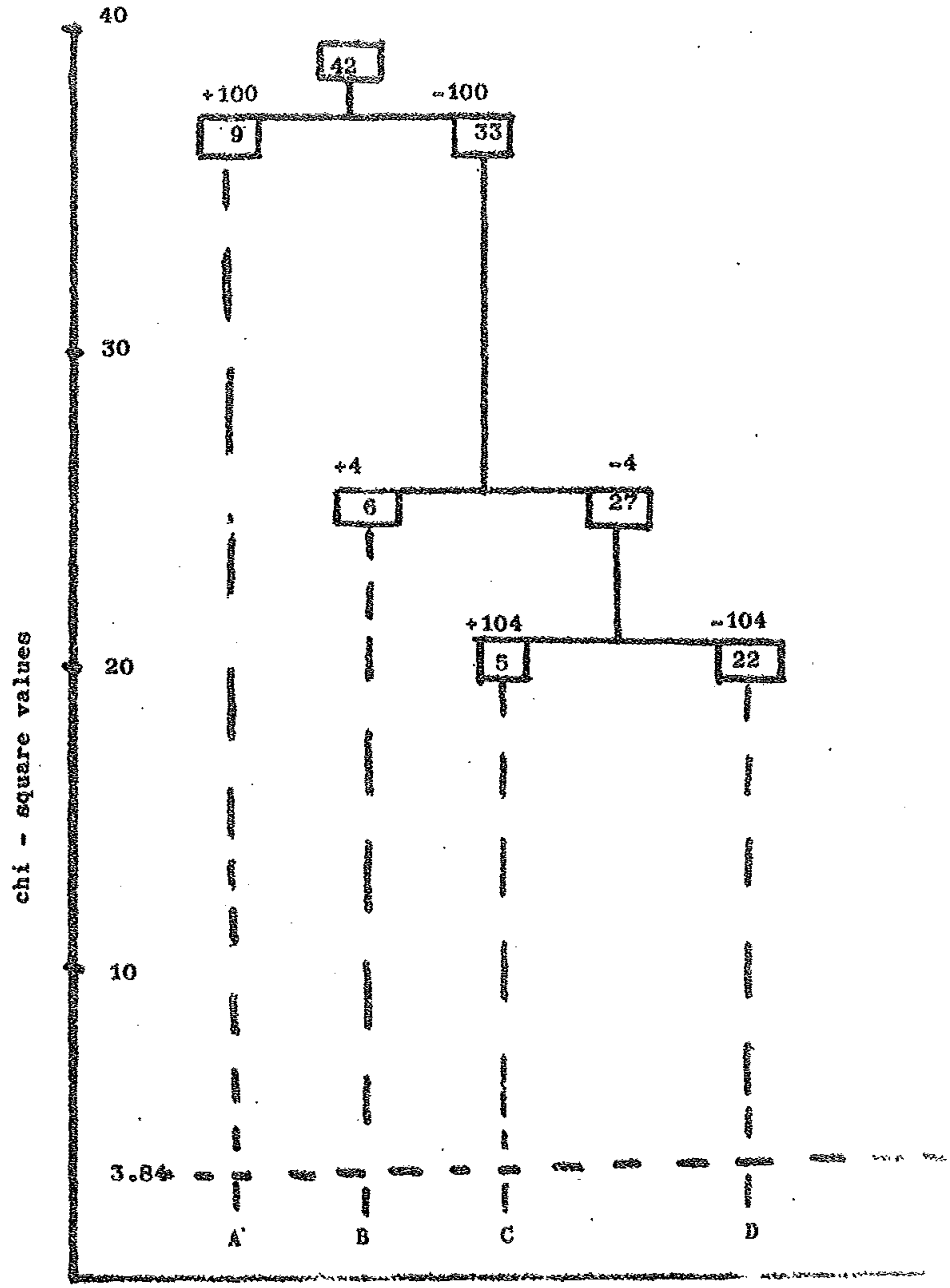


Fig. 3 - Dendrogram - showing the vegetation types after recombination of the groups (Normal Association Analysis)

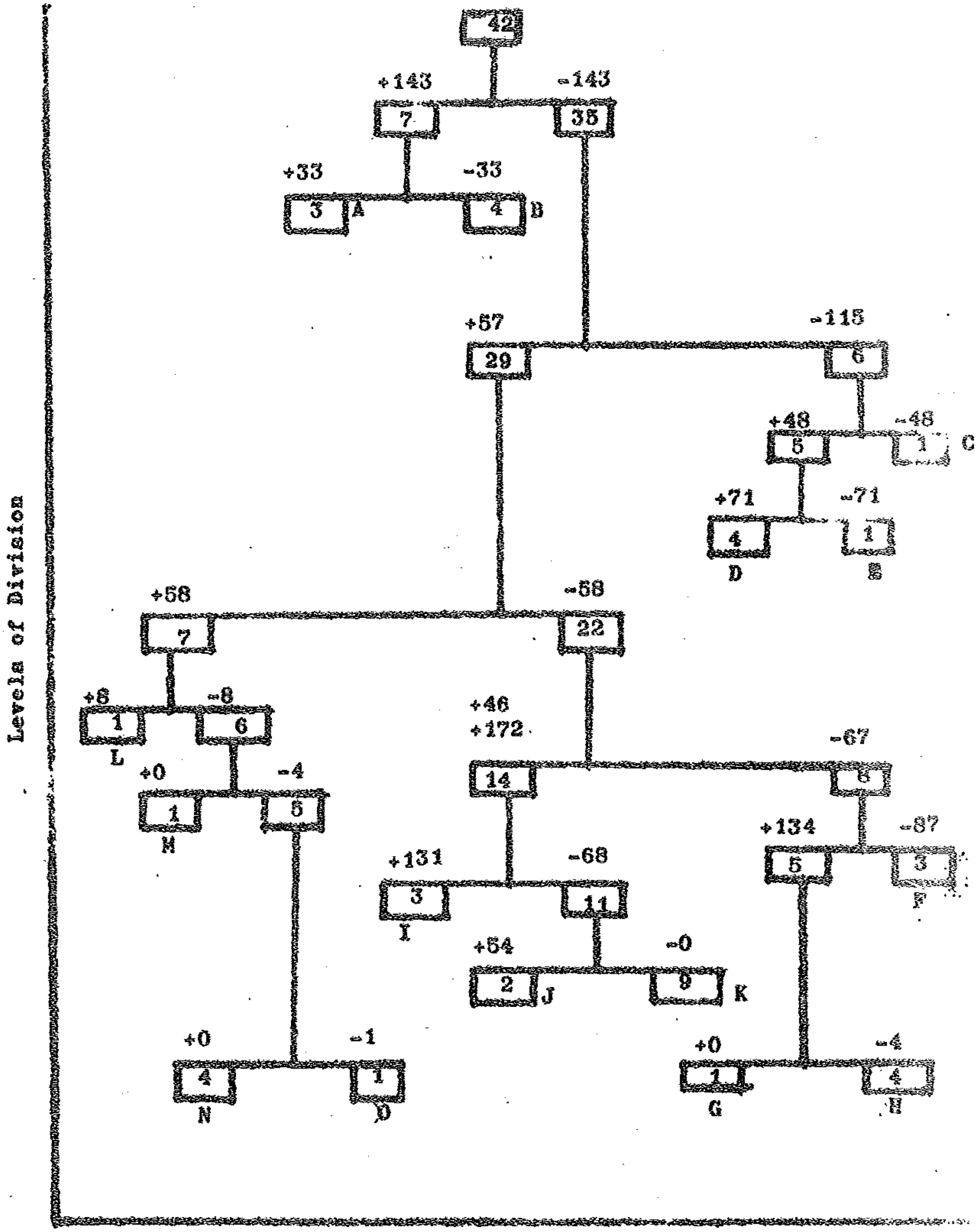


Fig. 4 - Dendrogram-showing the vegetation types. (Indicator species Analysis)

N.B - +0 = minimum indicator score for positive group is zero and -0 minimum indicator score for negative group is zero.

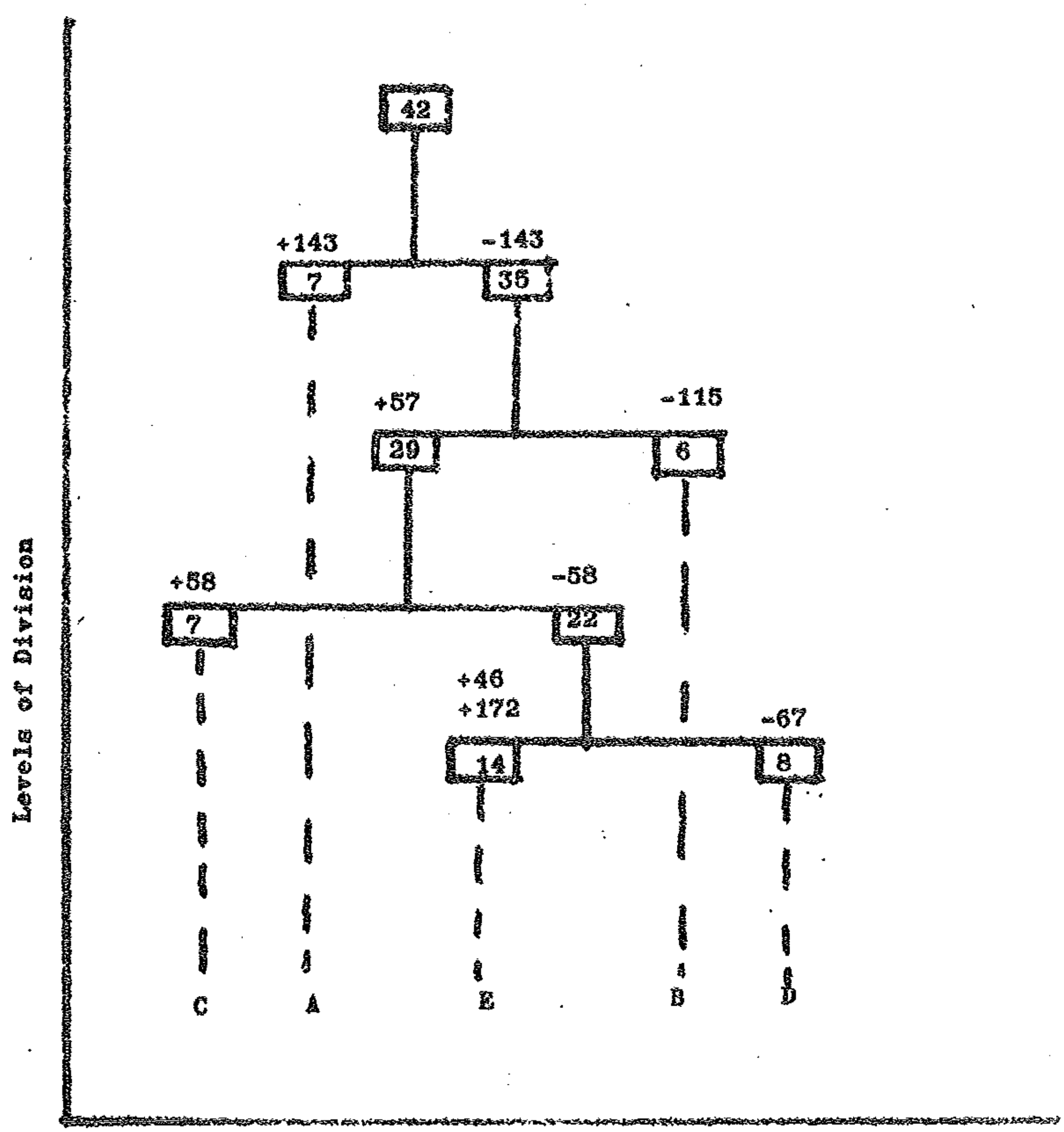


Fig. 5 - Dendrogram-showing the vegetation types after recombination of the groups. (Indicator Species Analysis)

6. DISCUSSION

6.1 Normal Association Analysis

The groups obtained through normal association analysis (A,B,C and D), do not follow the chronosequence of the study areas showing that the age of the rocks was not important for the distribution of the vegetation.

This can be seen clearly from the stand composition of the groups as follows.

Group A consists of stands from all study areas except from Kulumsa (fourth in chronosequence). It consists of two stands from Metahara, two stands from Sodere, three stands from Wolenchiti, one from Bofa and one from Balchi.

Group B consists of two stands from Sodere, one stand from Wolenchiti, one stand from Kulumsa and two stands from Balchi.

Group C consists of two stands from Metahara, one from Sodere, and two from Kulumsa.

Group D consists of stands from all six study areas. These are: three stands from Metahara, three stands from Sodere, two stands from Wolenchiti, four stands from Kulumsa and four stands from Balchi.

As mentioned in the results, the F value shows that only the parameter chroma was significantly different among the vegetation groups. Duncan's multiple range test has shown that chroma separates the vegetation into three distinct groups with C showing the highest, A and D medium and B the lowest means. This suggests that chroma is important for differentiation of the vegetation.

The frequency distribution of Spearman's rank correlation coefficients of the environmental parameters (table 6) has grouped the parameter pairs into strong positive, positive, negative and strong negative.

It would be enough to mention the two extremes ie. strong positive and strong negative inorder to show the trend.

The five parameter pairs which were strong positive were 1. slope and altitude, 2. percentage of exposed rock and potassium, 3. chroma and potassium 4. value and sodium and 5. conductivity and soil depth.

The six parameter pairs which were strong negative were 1. slope and percentage of exposed rock, 2. slope and chroma, 3. slope and potassium, 4. percentage of exposed rock and altitude, 5. chroma and conductivity, 6. chroma and soil depth.

The characteristic species for the vegetation groups obtained from normal association analysis are actually not correct as is shown below.

Heliotropium aegypticum, the characteristic species for Group A is present only in stand 16.

In Group B, Heliotropium aegypticum which is said to be absent is actually present in stand 41. Acacia senegal, the characteristics species of the group is present only in 50% of the stands.

In Group C, Acacia senegal which is said to be absent is actually present in two out of the five stands and Indigofera ambelacensis said to present is absent in all the five stands

Group D is characterized by the absence of Indigofera ambelacensis but, this species is present in 50% of the stands.

This may be because of misclassification as only 55 out of the 172 species were considered for classification as was mentioned in the results.

6.2 Indicator Species Analysis

The final groups obtained by indicator species analysis were five A,B,C,D and E) Figure 5.

The groups obtained from the indicator species analysis were found to closely follow the chronosequence for the study areas except for Group E. Group E consists of seven stands from Sodere (second in chronosequence) and seven stands from Bofa (fifth in chronosequence).

The Sodere basalts were deposited in the Holocene (recent) geological period while Bofa consists of basalts from the upper pliocene (7 million to recent). The sampling from Bofa basalts could have been taken from recent flows allowing the site to be grouped with Sodere. Besides, the two areas have geographical proximity and are almost on continuous ranges. Therefore, for this study it has been decided to consider Group E as being second in chronosequence.

Group A contains all the stands located in the Metahara area, the youngest lava flows and soil samples were not taken because there was very little soil. Therefore, the comparisons of environmental factors with vegetation groups were made only for groups B,C,D and E.

Indicator species analysis is a generalization of association analysis which retains the good features and avoids the high misclassification rate (Hill, Bunce and Shaw, 1975).

The groups produced by indicator species analysis have followed the chronosequence of the sites while the groups produced by normal association analysis have not.

The F values mentioned in the results have shown that chroma, value and potassium were significantly different among the vegetation groups.

According to Duncan's multiple range test, the parameters chroma and value separated the vegetation into two groups. These were Group E (second in chronosequence) with the highest mean and Groups B,C and D (fifth, third and fourth in chronosequence respectively) showing low means.

The parameter potassium separated the vegetation into two distinct groups. These were B and E (fifth and second in chronosequence respectively) and C and D (third and fourth in chronosequence respectively). Groups B and E, extremes in the chronosequence, ie. excluding Group A showed the highest means while C and D in the middle of the chronosequence showed low means.

The discussion so far suggests that chroma, value and potassium are important in the differentiation of the vegetation.

A comparison of the ranking for age and ranking for environmental parameters has been made to obtain Spearman's rank correlation coefficient as mentioned in the results. The results of these comparisons are discussed as follows.

The parameters conductivity, sodium and altitude have strong positive relations with the chronosequence.

The parameters slope and soil depth were positively related to chronosequence.

Chroma, value and potassium were negatively related to the chronosequence while percentage of exposed rock and hue show a strong negative relation to chronosequence.

Successional Stages

Groups A,B and C were found to have two types of pioneer plants: crustose lichen (grey) and crustose lichen (light green) while groups D and E have three types: crustose lichen (light green), crustose lichen (grey) and crustose lichen (orange).

Group A has a total of 12 species out of which there were 3 species of grass, 3 species of herbs, 3 species of shrubs and only 1 tree species.

Group B consists of 36 species of plant of which there were 8 species of grass, 17 species of herbs, 9 species of shrubs and 2 tree species.

Group C has a total of 68 species out of which there were 15 species of grass, 42 species of herbs, 6 species of shrubs and 5 tree species.

Group D consists of 55 species of plant out of which there were 9 species of grass, 47 species of herbs, 9 species of shrubs and 6 tree species.

Group E consists of 72 species of plant out of which there was 1 species of fern, 9 species of grass, 45 species of herbs, 12 species of shrubs and 5 species of trees.

The number of herb species was found to be higher than that of grasses, shrubs and trees. The number of grass and shrub species was almost the same in all the groups except that of C (third in chronosequence). In Group C, the number of grass species was more than twice that of shrub species.

From the discussion so far, it can be concluded that indicator species analysis has given a more meaningful contrast of environmental factors than normal association analysis. Indicator species analysis has also established the chronosequence of the sites in vegetation distribution which the normal association analysis has failed to show. Therefore, successional trends were not established for the groups from normal association analysis while this has been established for the groups from indicator species analysis which is described as follows.

Successional Trends

Successional trends have been established based on the chronosequence by considering plants which are unique and the indicator species for each stage.

1. Metahara (Group A)

Rhynchelytrum sp was found to be the indicator species and the plants associated with it were:-

Shrub - Linderbergia sinacia. Tree Ficus populifolia.

2. Sodere + Bofa (Group E)

The indicator species at higher levels in the dichotomy were "crustose lichen" (light green) and "crustose lichen" (orange) and Cissus quadriangularis and Zizyphus spina-christi at the level of division of the group. The plants associated with the later two indicator species were as follows:-

Grasses - Sporobolus festivus, Aristida adscensionsis and Cynodon dactylon. Herbs - Vernonia cinarescens, Barleria eranthemoides, Argemone mexicana, Erucastrum arabicum, Commelina africana, Caralluma socotrana, Chenopodium botrys, Cyphostemma cyphopetallum, Amaranthus caudatus, Coccinia grandis, Endostemon terticaulis, Becium sp, Euphorbia hirta, Indifogera hochstetteri, Orthosiphon pallidus, Alternanthera pungens, Kalanchoe crenata, Solanum histifolium, Eulophia sp, Sida alba, Guizotia Scabra, Barleria orbicularis, and Cassia italica.

Shrubs - Croton dichogamus, Cassia occidentalis, Blepharis ciliarisis.

Trees - Zizyphus spina - christi, and Ficus palmata.

3. Wolenchiti (Group C)

The indicator species at a higher level of dichotomy was Kalanchoe marmorata and "crustose lichen" (light green) at the level of division of the group. The species associated with the indicator species were as follows:-

Fern - Adiantum incisum

Sedge - Cyprus cf. haspam.

Herbs - Commelina albescens, Helichrysum schimperi, Indigofera colutae, Aerva persica, Polygala sphenoptera, Balinvella dichotoma, Cassia mimosoides, Isoglossa sp. aff. laxa, Vernonia sp, Ipomea carica, Abutilon figarianum, Chascanum hilderbrandtii, Euphorbia schimperiana, Conyza pedunculata, Barleria acanthoides, Dicoma tomentosa, Solanum polyanthemum, Chenopodium album, Achyranthus sp, Hibiscus aponeurus, Endostemon tenuiflorus, Senecio discifolius, Pupalia lappacea, Ipomoea blepharosephala, and Glycine weighti.

Shrubs - Grewia villosa and Dombeya schimperianum.

Trees - Boswelia papyrifera and Ximenia americana.

4. Kulumsa (Group D)

The indicator species at a higher level in the dichotomy were "crustose lichen" (light green) and "crustose lichen" (orange) and the indicator species at the level of division of the group was Delphinium dasycaulon and the species

Table 7. Distribution of plants unique to each age group

Chronosequence

	1	2	3	4	5
Ferns	-	-	1	-	-
Sedges	-	-	1	-	-
Grasses	1	3	10	4	4
Herbs	-	23	25	3	6
Shrubs	1	3	3	3	6
Trees	1	2	2	1	1
Total	3	31	42	11	17

N.B - 1 = Metahara 2 = Sodere + Bofa

3 = Wolenchiti 4 = Kulumsa

5 = Balchi

associated with it were:-

Grasses - Aristida kenyensis, Chloris Pycnothrix, Dactyloctenium aegypticum and Rhynchelytrum repens.

Herbs - Calpurina aurea, Justica caerulea, Senecio abyssinicus, Aspilia mossambicensis, Helinus mystacinus, Crotalaria pycnostachya, Cynoglossum caerulum, Pterocephohalus frutescens, Achyrospermum schimperi, Monsonia augistifolia, Polygala albida, Pentanesia ouranogyne, Phyllanthus maderaspatensis Alysicarpus sp, Notonia semperviva.

Shrubs - Tagetus minuta, Tapinanthus globiferus and Rhus abyssinica.

5. Balchi (Group B)

The indicator species at a higher level in the dichotomy was Rhynchelytrum sp and Kalanchoe marmorata at the level of division of the group and the species associated with it were:-

Grasses - Bothriochloa radicans, sporobolus pyramidalis, Sporobolus panicoides, and Urochloa panicoides.

Herbs - Senecio sp, Argyrolobium arabicum, Monechma debile, and Rhyncosia sp.

Shrubs - Dodonea viscosa, Sageretia thea, Loranthus globiferus, Carissa edulis, Pterolobium stellatum, and Ferulla communis.

Trees - Euclea schimperi.

The number of ferns, sedges, grasses, herbs, shrubs and trees unique to each age group are summarized in table 7.

From the distribution of plant species given in table 7, Wolenchiti (third in chronosequence) is the only site having a fern and a sedge species.

The grass species increased in number from one in the first age level to three in the second age level and became ten in the third. The fourth and fifth age levels have four species of grasses each.

The trend of grass species shows an increase from the first to the third age level and falls to the same level in the fourth and fifth age levels.

The number of herb species increases from 23 in the second age level to 25 in the third, then the number decreases to 15 in the fourth and further to 4 in the fifth.

A comparison of shrub species shows that the number increases from one in the first to three in the second, third and fourth age levels and increases to six in the fifth.

The trend of tree species shows that it increases from one to two in the second and third and decreases to one in the fourth and fifth age levels.

Wolenchiti (third age level) has been found to have the highest number of grass and herb species when compared to the other sites. This site has also been found to have the highest total number of species compared to the other sites in the study areas.

In general, the successional trend shows a fast increase in number of species upto the third age level and a decrease 'n number of species in the next age levels.

These results are in agreement with the results obtained by (Swaine and Hall, 1983), (Habeck, 1968), (Bazzaz, 1968), (Henry and Swan, 1974), (Nicholson and Monk, 1974) and Tramer, 1975).

Succession on cleared forest land was studied by Swaine and Hall (1983), for a period of five years over 800 sq.m. of sample area and they found out that tree density increased rapidly after one year and showed a decline at the end of five years.

Habeck (1968), studied forest succession after glacial retreat and found out that the average number of species in each of the six successional stages studied showed a gradual reduction in species diversity at later stages of succession.

According to Bazzaz (1968), succession on abandoned fields does not usually result in a change in floristic composition of the vegetation and changes are mainly on the relative importance of species.

Henry and Swan (1974), studied forest succession and found out that autogenic succession did not contribute significantly to compositional changes, whereas disturbance such as fire was an important mediator of such changes.

A study of species diversity in old-field succession on the Georgia piedmont by Nicholson and Monk (1974) has shown that species diversity increased rapidly following establish ment and then at a decreasing rate throughout the remainder of succession.

A similar study has also been done by Trammer (1975) on an old field in Ohio over a period of 4 years and the highest number of species was obtained in the first year and a marked decline in the fourth year.

Bazzaz (1975) attributes the decrease in number of species due to strong dominance by species with allelopathic chemicals or other effective interference methods.

In my study areas, the decline in number of species in the fourth and fifth age levels could be attributed to human interference. It has been observed that Kulumsa (the fourth age level) and Balchi (the fifth age level) have relatively more human interference compared to the other sites.

The environmental factors which increase with the age of the sites (conductivity, sodium, altitude, slope and soil depth) or those which decrease with the age of the sites (chroma) potassium, percentage of exposed rock and hue) value could also be responsible for the decline in number of species although it may require further study inorder to be conclusive.

Other workers like (Viereck, 1966), Reiners, Worley and Lawrence, 1971), (Douglas and Ballard, 1971), (Shure and Rogsdale, 1977) have studied various aspects of succession and found results which were contrary to what has been described so far ie. species numbers have been observed to increase with successive successional stages.

Viereck (1966) studied plant succession and soil development in a series of five stands on glacial outwash and observed that vegetation development progresses from scattered mat plants to a climax tundra stage.

Eight sites of known age were sampled in an area of glacial retreat in Alaska and species numbers increased rapidly in the first 100 years, then more gradually to reach a maximum level at the final steady state showing an increase in species number with time (Reiners, Worley and Lawrence,1971).

According to Douglas and Ballard (1971) Alpine plant communities were studied to know the effect of fire on the vegetation and found out that there was an overall increase in species numbers. Similar results were also obtained by Shure and Ragsdale (1977) on granite outcrop surfaces and found out that biotic diversity increases throughout primary succession.

The results of my study can be considered to be in agreement with the results of the above authors when only the terminal stages are compared. The number of plant species increases from a total of 3 in Metahara (the youngest basaltic lava flow) to 17 plant species in Balchi (the oldest basaltic lava flow).

7. CONCLUSION

The objective of this study was to establish vegetation succession on basaltic lava flows of different ages.

The data were analyzed by computer using normal association analysis and indicator species analysis to obtain vegetation groups.

The vegetation groups obtained from the indicator species analysis were used for establishing successional trends because these groups followed the chronosequence of the basaltic lava flows.

The successional trend has shown a fast increase in number of species upto the third age level and a decrease in the next age levels. However, an increase in total number of species was found if only the terminal stages in the chronosequence are considered.

The parameters conductivity, sodium, altitude, slope and soil depth were found to be positively related to the chronosequence while the parameters chroma, value, potassium, percentage of exposed rock and hue were found to be negatively related to the chronosequence.

Table 8. Appendices

Appendix A

Environmental Data

Stand No	Slope in 0°	Aspect	Altitude (in meters)	Study Area
1	0	N.E	1080	Metahara
2	0	"	"	"
3	0	"	"	"
4	0	"	"	"
5	0	"	"	"
6	0	"	"	"
7	0	"	"	"
8	5	N30°E	1570	Sodere
9	10	N60°S.E	1560	"
10	15	N50°S.E	1400	"
11	10	N70°E	1400	"
12	15	N65°E	1410	"
13	5	N40°S.E	1420	"
14	10	N70°S.E	1420	"
15	5	N25°E	1300	Wolenchiti
16	5	N60°S.E	1320	"
17	10	N60°S.E	1320	"
18	5	N80°S.E	1320	"
19	5	N70°S.E	1300	"
20	5	N60°S.E	1290	"
21	5	N60°E	1300	"

Appendix A (cont'd)

Stand No	Slope in 0^{o}	Aspect	Altitude (in meters)	Study Area
22	5	N70°S.E	1910	Kulumsa
23	10	N20°S.E	1900	"
24	10	N90°E	1910	"
25	15	N70°E	1900	"
26	5	N75°E	1910	"
27	10	N60°E	1905	"
28	5	N50°E	1910	"
29	5	N70°E	1430	Bofa
30	10	N70°E	1430	"
31	5	N80°E	1490	"
32	10	N40°E	1490	"
33	10	N50°E	1490	"
34	10	N40°E	1485	"
35	5	N45°E	1490	"
36	15	N60°E	1930	Balchi
37	10	N30°E	1910	"
38	5	N40°E	1890	"
39	10	N75°E	1920	"
40	10	N20°E	1930	"
41	5	N40°E	1930	"
42	5	N70°E	1940	"

Appendix B

Percentage of Exposed Rock in the Stands in each of the Study Areas

STAND NUMBER							Total	Study Area
1	2	3	4	5	6	7		
V.A.R	V.A.R	V.A.R	V.A.R	V.A.R	V.A.R	V.A.R	V.A.R	Metahara
70	80	80	85	75	85	80	79.28	Sodere
40	25	85	70	60	70	75	60.71	Wolenchiti
85	85	65	30	30	20	30	49.28	Kulumsa
30	40	30	30	50	60	75	45.00	Bofa
75	80	20	40	15	35	10	39.28	Balchi

V.A.R = Virtually all rock

Appendix C

Soil colour YR at various depth (dry)

Stand No.	Soil depth in Cm				Study Area
	0 - 10	10 - 20	20 - 30	30 - 40	
1	-	-	-	-	Metahara
2	-	-	-	-	"
3	-	-	-	-	"
4	-	-	-	-	"
5	-	-	-	-	"
6	-	-	-	-	"
7	-	-	-	-	"
8	7.5 5/3	R.E	R.E	R.E	Sodere
9	5 5/4	5 4/4	R.E	R.E	"
10	5 5/4	R.E	R.E	R.E	"
11	2.5 5/4	R.E	R.E	R.E	"
12	2.5 3/4	2.5 5/4	2.5 6/4	2.5 6/4	"
13	2.5 5/2	R.E	R.E	R.E	"
14	7.5 5/4	7.5 5/4	R.E	R.E	"
15	7.5 5/4	7.5 5/4	R.E	R.E	Wolenchiti
16	7.5 4/4	R.E	R.E	R.E	"
17	5 4/1	R.E	R.E	R.E	"
18	5 4/1	5 5/1	R.E	R.E	"
19	5 4/1	R.E	R.E	R.E	"
20	5 3/1	5 3/2	5 3/2	R.E	"
21	5 3/1	5 3/1	R.E	R.E	"
22	7.5 5/4	7.5 5/4	R.E	R.E	Kulumsa

Appendix C (cont'd)

Stand No.	Soil depth in Cm				Study Area
	0 - 10	10 - 20	20 - 30	30 - 40	
23	5 6/3	R.E	R.E	R.E	Kulumsa
24	2.5 5/2	2.5 5/4	R.E	R.E	"
25	5 3/2	R.E	R.E	R.E	"
26	2.5 5/4	R.E	R.E	R.E	"
27	5 6/3	R.E	R.E	R.E	"
28	5 6/3	R.E	R.E	R.E	"
29	7.5 6/3	R.E	R.E	R.E	Bofa
30	5 8/2	R.E	R.E	R.E	"
31	5 6/3	R.E	R.E	R.E	"
32	7.5 6/4	R.E	R.E	R.E	"
33	7.5 6/4	7.5 6/4	R.E	R.E	"
34	5 5/4	R.E	R.E	R.E	"
35	7.5 5/4	R.E	R.E	R.E	"
36	2.5 5/2	R.E	R.E	R.E	Balchi
37	2.5 5/2	R.E	R.E	R.E	"
38	2.5 5/4	2.5 6/4	2.5 4/4	2.5 5/4	"
39	2.5 4/2	2.5 4/4	R.E	R.E	"
40	2.5 5/4	R.E	R.E	R.E	"
41	10R 2/1	R.E	R.E	R.E	"
42	10R 2/1	10R 2/1	R.E	R.E	"

Appendix D

Soil colour YR at Various Depths (Wet)

Stand No.	Soil Depth in Cm				Study Area
	0 - 10	10 - 20	20 - 30	30 - 40	
1	-	-	-	-	Metahara
2	-	-	-	-	"
3	-	-	-	-	"
4	-	-	-	-	"
5	-	-	-	-	"
6	-	-	-	-	"
7	-	-	-	-	"
8	2.5 5/4	R.E	R.E	R.E	Sodere
9	2.5 4/4	5 4/3	R.E	R.E	"
10	5 4/3	R.E	R.E	R.E	"
11	5 5/4	R.E	R.E	R.E	"
12	2.5 5/4	2.5 4/4	2.5 4/4	2.5 6/4	"
13	2.5 4/2	R.E	R.E	R.E	"
14	2.5 3/2	5 4/1	R.E	R.E	"
15	5 3/1	5 4/1	R.E	R.E	Wolenchiti
16	5 4/1	R.E	R.E	R.E	"
17	7.5 3/0	R.E	R.E	R.E	"
18	7.5 4/0	5 4/1	R.E	R.E	"
19	7.5 4/0	R.E	R.E	R.E	"
20	5 3/1	5 5/1	5 4/1	R.E	"
21	7.5 3/0	7.5 4/0	R.E	R.E	"
22	2.5 4/4	2.5 4/4	R.E	R.E	Kulumsa

Appendix D (Cont'd)

Stand No.	Soil Depth in Cm				Study Area
	0 - 10	10 - 20	20 - 30	30 - 40	
23	5 4/3	R.E	R.E	R.E	Kulumsa
24	2.5 4/4	2.5 6/4	R.E	R.E	"
25	5 3/2	R.E	R.E	R.E	"
26	5 5/4	R.E	R.E	R.E	"
27	5 4/4	R.E	R.E	R.E	"
28	5 4/3	R.E	R.E	R.E	"
29	2.5 4/2	R.E	R.E	R.E	Bofa
30	5 5/4	R.E	R.E	R.E	"
31	2.5 4/4	R.E	R.E	R.E	"
32	2.5 5/2	R.E	R.E	R.E	"
33	2.5 4/2	5 4/3	R.E	R.E	"
34	2.5 4/4	R.E	R.E	R.E	"
35	5 5/4	R.E	R.E	R.E	"
36	5 5/4	R.E	R.E	R.E	Balchi
37	2.5 5/2	R.E	R.E	R.E	"
38	5 5/4	5 4/3	5 4/3	5 6/3	"
39	5 3/3	5 3/3	R.E	R.E	"
40	5 6/4	R.E	R.E	R.E	"
41	5 3/2	R.E	R.E	R.E	"
42	7.5 5/4	7.5 3/2	R.E	R.E	"

Appendix E

Electrical Conductivity of the Soil Samples

At various depths in Mmhos/Cm

Stand No.	Depth in Cm				Study Area
	0 - 10	10 - 20	20 - 30	30 - 40	
1	-	-	-	-	Metahara
2	-	-	-	-	"
3	-	-	-	-	"
4	-	-	-	-	"
5	-	-	-	-	"
6	-	-	-	-	"
7	-	-	-	-	"
8	51.68	R.E	R.E	R.E	Sodere
9	9.52	10.33	R.E	R.E	"
10	7.88	R.E	R.E	R.E	"
11	11.1	R.E	R.E	R.E	"
12	43.52	27.2	12.24	7.61	"
13	11.15	R.E	R.E	R.E	"
14	12.78	R.E	R.E	R.E	"
15	16.32	12.78	R.E	R.E	Wolenchiti
16	12.51	R.E	R.E	R.E	"
17	10.06	R.E	R.E	R.E	"
18	11.69	11.15	R.E	R.E	"
19	9.24	R.E	R.E	R.E	"
20	21.76	24.48	24.48	R.E	"
21	16.32	12.51	R.E	R.E	"

Appendix E (cont'd)

Stand No.	Depth in Cm				Study Area
	0 - 10	10 - 20	20 - 30	30 - 40	
22	19.04	21.76	R.E	R.E	Kulumsa
23	11.15	R.E	R.E	R.E	"
24	19.04	16.32	R.E	R.E	"
25	10.88	R.E	R.E	R.E	"
26	14.96	R.E	R.E	R.E	"
27	16.32	R.E	R.E	R.E	"
28	16.32	R.E	R.E	R.E	"
29	10.06	R.E	R.E	R.E	Bofa
30	7.34	R.E	R.E	R.E	"
31	8.7	R.E	R.E	R.E	"
32	5.57	R.E	R.E	R.E	"
33	12.24	12.06	R.E	R.E	"
34	7.07	R.E	R.E	R.E	"
35	8.16	R.E	R.E	R.E	"
36	21.76	R.E	R.E	R.E	Balchi
37	16.32	R.E	R.E	R.E	"
38	19.04	16.32	19.04	9.76	"
39	14.96	11.42	R.E	R.E	"
40	11.42	R.E	R.E	R.E	"
41	10.60	R.E	R.E	R.E	"
42	14.96	12.49	R.E	R.E	"

Appendix F

pH of the Soil Samples at Various Depth

Stand No.	Depth in Cm				Study Area
	0 - 10	10 - 20	20 - 30	30 - 40	
1	-	-	-	-	Metahara
2	-	-	-	-	"
3	-	-	-	-	"
4	-	-	-	-	"
5	-	-	-	-	"
6	-	-	-	-	"
7	-	-	-	-	"
8	7.2	R.E	R.E	R.E	Sodere
9	7.2	7.4	R.E	R.E	"
10	6.9	R.E	R.E	R.E	"
11	6.5	R.E	R.E	R.E	"
12	7.2	6.5	6.9	7.2	"
13	6.7	R.E	R.E	R.E	"
14	6.8	R.E	R.E	R.E	"
15	6.7	6.5	R.E	R.E	Wolenchiti
16	6.4	R.E	R.E	R.E	"
17	6.5	R.E	R.E	R.E	"
18	6.6	6.9	R.E	R.E	"
19	7.2	R.E	R.E	R.E	"
20	6.2	6.7	6.5	R.E	"
21	6.7	6.8	R.E	R.E	"

Appendix F (cont'd)

Stand No.	Depth in Cm				Study Area
	0 - 10	10 - 20	20 - 30	30 - 40	
22	7.3	7.5	R.E	R.E	Kulumsa
23	6.6	R.E	R.E	R.E	"
24	7.2	6.3	R.E	R.E	"
25	6.0	R.E	R.E	R.E	"
26	7.2	R.E	R.E	R.E	"
27	7.2	R.E	R.E	R.E	"
28	6.3	R.E	R.E	R.E	"
29	7.6	R.E	R.E	R.E	Bofa
30	7.6	R.E	R.E	R.E	"
31	7.4	R.E	R.E	R.E	"
32	7.2	R.E	R.E	R.E	"
33	7.0	7.6	R.E	R.E	"
34	6.8	R.E	R.E	R.E	"
35	6.9	R.E	R.E	R.E	"
36	7.0	R.E	R.E	R.E	Balchi
37	6.3	R.E	R.E	R.E	"
38	6.5	6.9	7.4	7.2	"
39	6.9	6.8	R.E	R.E	"
40	6.5	R.E	R.E	R.E	"
41	6.6	R.E	R.E	R.E	"
42	6.0	6.2	R.E	R.E	"

Appendix G

Sodium content of the soil samples at various depths in PPM

Stand No.	Depth in Cm				Study Area
	0 – 10	10 – 20	20 – 30	30 – 40	
1	–	–	–	–	Metahara
2	–	–	–	–	"
3	–	–	–	–	"
4	–	–	–	–	"
5	–	–	–	–	"
6	–	–	–	–	"
7	–	–	–	–	"
8	50	R.E	R.E	R.E	Sodere
9	40	50	R.E	R.E	"
10	60	R.E	R.E	R.E	"
11	50	R.E	R.E	R.E	"
12	60	40	60	40	"
13	30	R.E	R.E	R.E	"
14	70	R.E	R.E	R.E	"
15	40	70	R.E	R.E	Wolenchiti
16	50	R.E	R.E	R.E	"
17	60	R.E	R.E	R.E	"
18	60	50	R.E	R.E	"
19	40	R.E	R.E	R.E	"
20	60	50	60	R.E	"
21	50	90	R.E	R.E	"

Appendix G (cont'd)

Stand No.	Depth in Cm				Study Area
	0 - 10	10 - 20	20 - 30	30 - 40	
22	60	40	R.E	R.E	Kulumsa
23	80	R.E	R.E	R.E	"
24	50	80	R.E	R.E	"
25	90	R.E	R.E	R.E	"
26	20	R.E	R.E	R.E	"
27	40	R.E	R.E	R.E	"
28	50	R.E	R.E	R.E	"
29	60	R.E	R.E	R.E	Bofa
30	50	R.E	R.E	R.E	"
31	50	R.E	R.E	R.E	"
32	70	R.E	R.E	R.E	"
33	60	50	R.E	R.E	"
34	30	R.E	R.E	R.E	"
35	50	R.E	R.E	R.E	"
36	60	R.E	R.E	R.E	Balchi
37	60	R.E	R.E	R.E	"
38	60	60	70	80	"
39	60	60	R.E	R.E	"
40	70	R.E	R.E	R.E	"
41	60	R.E	R.E	R.E	"
42	30	50	R.E	R.E	"

Appendix H

Potassium Content of the Soil Samples at Various depth in PPM

Stand No.	Depth in Cm				Study Area
	0 - 10	10 - 20	20 - 30	30 - 40	
1	-	-	-	-	Metahara
2	-	-	-	-	"
3	-	-	-	-	"
4	-	-	-	-	"
5	-	-	-	-	"
6	-	-	-	-	"
7	-	-	-	-	"
8	170	R.E	R.E	R.E	Sodere
9	73	93	R.E	R.E	"
10	69	R.E	R.E	R.E	"
11	62	R.E	R.E	R.E	"
12	89	44	38	33	"
13	118	R.E	R.E	R.E	"
14	47	47	R.E	R.E	"
15	199	105	R.E	R.E	Wolenchiti
16	113	R.E	R.E	R.E	"
17	98	R.E	R.E	R.E	"
18	101	80	R.E	R.E	"
19	104	R.E	R.E	R.E	"
20	72	60	86	R.E	"
21	89	76	R.E	R.E	"

Appendix H (cont'd)

Stand No.	Depth in Cm				Study Area
	0 - 10	10 - 20	20 - 30	30 - 40	
22	184	92	R.E	R.E	Kulumsa
23	166	R.E	R.E	R.E	"
24	98	78	R.E	R.E	"
25	99	R.E	R.E	R.E	"
26	191	R.E	R.E	R.E	"
27	195	R.E	R.E	R.E	"
28	196	R.E	R.E	R.E	"
29	70	R.E	R.E	R.E	Bofa
30	56	R.E	R.E	R.E	"
31	58	R.E	R.E	R.E	"
32	59	R.E	R.E	R.E	"
33	27	79	R.E	R.E	"
34	46	R.E	R.E	R.E	"
35	64	R.E	R.E	R.E	"
36	56	R.E	R.E	R.E	Balchi
37	55	R.E	R.E	R.E	"
38	37	22	14	19	"
39	188	99	R.E	R.E	"
40	32	R.E	R.E	R.E	"
41	34	R.E	R.E	R.E	"
42	49	31	R.E	R.E	"

Remarks on Appendices C - H

Soil samples were not taken from the Metahara study area in the vicinity of L. Beseka because this area is Virtually all rocks. There is very little soil formation in between the boulders and it was physically impossible to auger from the top of the slippery and sharp edged boulders.

R.E = Rock encountered

7.5 YR 5/4, 3/2 - brown

7.5 YR 6/4 - Light brown

5 YR 4/4, 5/4, 4/3 - Reddish brown

5 YR 6/3, 6/4 - Light reddish brown

5 YR 3/3, 3/2, 3/4 - Dark reddish brown

2.5 YR 5/2, 4/2 - Weak red

5 YR 5/1 - Grey

10R 2/1 - Reddish black

5YR 8/2 - Pinkish white

7.5 YR 6/4 - Dark brown

5 YR 3/1, 3/0 - Dark grey

Appendix I

List of plants recorded in the Study Areas

1. *Abutilon figarianum* Webb.
2. *Abutilon* sp.
3. *Acacia nilotica* (L) Wild. ex. Del.
4. *Acacia senegal* (L) Wild.
5. *Achyranthes aspera* L.
6. *Achyranthes* sp.
7. *Achyrospermum schimperia* (Hochst. ex. Biq.) Perkins.
8. *Actinopteris semiflabellata* (L.f) Link.
9. *Adiantum incisum* Forsk.
10. *Aerva persica* (Brum) Merill.
11. *Aloe trichosantha* Berger.
12. *Alternanthera pungens* HBK.
13. *Alysicarpus* sp.
14. *Amaranthus caudatus* L.
15. *Arthemis tigreensis* J. Gay. Ex. A. Rich.
16. *Argemone mexicana* L.
17. *Aristida adscensionsis* L.
18. *Aristida kenyensis* Henr.
19. *Argyrolobium arabicum* Decne Jb. & sp.
20. *Aspilia mossambicensis* (Oliv) Willd.
21. *Balanites aegyptica* Del.
22. *Barleria acanthoides* Vahl.
23. *Barleria eranthemoides* R.Br. ex. Clarke.
24. *Barleria orbicularis* T. Anders.
25. *Becium* sp.
26. *Blainvella dichotoma* (Morr).

Appendix I (cont'd)

27. *Blepharis ciliarsis* (L). Burtt.

28. *Blepharis maderaspatensis* (L) Roth.

29. *Bothriochloa radicans* (Lehm). Camus.

30. *Boswelia papyrifera* (Del). Hochst.

31. *Brachiaria deflexa* (Schaum). Hubb.

32. *Calpurnia aurea* (Lam). Benth.

33. *Capparice Tomentosa* (Lam). Benth.

34. *Caralluma socotrana* Vierch.

35. *Carissa edulis* (Forsk) Vahl.

36. *Cassia italica* (Mill) Lam.

37. *Cassia occidentalis* L.

38. *Cassia mimosoides* L.

39. *Cenchrus cilarsis* L.

40. *Chascanum hilderbrandtii* (Vatke) Gilett.

41. *Chenopodium album* L.

42. *Chenopodium botrys* Linn.

43. *Chloris pycnothrix* Trin.

44. *Chloris roxburghiana* Schult.

45. *Chloris virgata* Sw.

46. *Cissus quadriangularis* L.

47. *Cleome schweinfurthii* Gilg.

48. *Clerodendron alatum* Gurke.

49. *Coccinia grandis* (L) Voight.

50. *Commelina africana* L.

51. *Commelina albescens* Hassk.

52. *Conyza pedunculata* (Oliv) H. Willd.

53. *Crotalaria pycnostachya* Benth.

Appendix I (cont'd)

54. *Croton dichogamus* Pax.

55. *Croton macrostachyus* Hochst. ex. Del.

56. Crustose lichen (grey).

57. Crustose lichen (light green).

58. Crustose lichen (orange).

59. *Cynodon aethiopicum* Clayton & Harlan.

60. *Cynodon dactylon* (L) Pers.

61. *Cynoglossum coerulum* Steud - ex - Dc.

62. *Cypholepis yemenica* (Schwft) Chiov.

63. *Cyphostemma cyphopetallum* (Fresen) Dese.

64. *Cyprus* cf. *haspam* L.

65. *Dactyloctenium aegypticum* L. Willd.

66. *Datura stramonium* Linn.

67. *Delphinium dasycaulon* Fresen.

68. *Dichrostachys cenerea* (L) Wight & Arn.

69. *Dicoma tomentosa* cass.

70. *Digitaria* sp.

71. *Dodonea viscosa* (L) Jacq.

72. *Dombeya schimperianum* A. Rich

73. *Endostemon tenuiflorus* (Benth) Ashby

74. *Endostemon terticaulis* (Poir) Ashby.

75. *Enteropogan macrostachys* (A. Rich) Benth.

76. *Eragrostis aspera* Jacq Nees.

77. *Eragrostis gangetica* (Rox) Steud.

78. *Erucastrum arabicum* Fish & Mey.

79. *Euclea schimperi* (Dc.) Dandy.

80. *Eulophia* sp.

Appendix I (cont'd)

81. Euphorbia hirta L.

82. Euphorbia schimperiana Schule.

83. Evolvules alsinoides L.

84. Ferrula communis L.

85. Ficus palmata (Forsk).

86. Ficus populifolia Vahl.

87. Galinsoga parviflora Cav.

88. Glycine weighti Wight & Arn Verde.

89. Grewia bicolor Juss (L).

90. Grewia erythraea Schweinf.

91. Grewia villosa Willd.

92. Guizotia scabra (Vis) Chiov.

93. Harpachne schimperi A. Rich.

94. Helichrysum gluacum D.C.

95. Helichrysum schimperi (Moeser).

96. Helichrysum sp.

97. Helinus mystacinus (Act) E.

98. Heteropogan contortus (Stapf & Hubb).

99. Hibiscus aponeurus Spargne & Hatch.

100. Heliotropium aegypticum Lehnn.

101. Hyparrhenia anthistriodes (A. Rich) Stapf.

102. Hyparrhenia finitima (Hochst). Anderss. ex Stapf.

103. Hypoestus verticillaris (Limn.f). Roem & Schult.

104. Indigofera ambelacensis Schweinf.

105. Indigofera colutea (Burm.f) Merr.

106. Indigofera hochstetteri Bak.

107. Ipomoea blepharosephala Hochst.

Appendix I (cont'd)

108. *Ipomoea carica* (L) Sweet.

109. *Ipomoea obscura* (L) Ker - Gawl.

110. *Isoglossa* sp. aff. lax (Oliv).

111. *Jasminium floribundum* R.Br ex Fresen.

112. *Justica caerulea* (Forsk).

113. *Justica diffusa* Willd.

114. *Kalanchoe crenata* Har.

115. *Kalanchoe marmorata* Bak.

116. *Kohautia coccinia* Royle.

117. *Lantana trifolia* L.

118. *Lasiocorys abyssinica* Benth.

119. *Leucas martinicensis* (Jacq) R.Br.

120. *Linderbergia sinacia* Benth.

121. *Linum strictum* L.

122. *Loranthus globiferus* Rich.

123. *Medicago polymorpha* L.

124. *Monechma debile* (Forsk) Nees.

125. *Monsonia augistifolia* A. Rich.

126. *Nicandra physaloides* (L) Gaertn.

127. *Notonia semperviva* (Forsk) Asch.

128. *Orthosiphon pallidus* Royl ex. Benth.

129. *Panicum atrosanguineum* A. Rich

130. *Pentanesia ouranogyne* S. Moore.

131. *Pergularia daemia* (Forsk) Chiov.

132. *Phyllanthus maderaspatensis* L.

133. *Premna schimperi* Engl.

134. *Polygala albida* Shinz.

Appendix I (cont'd)

135. *Polygala sphenoptera* Fresen.

136. *Peterolobium stellatum* (Forsk) Brenan.

137. *Pterocephohalus frutescens* Hochst.

138. *Pupalia lappacea* (L) Juss.

139. *Reichardia tangitana* (L) Roth.

140. *Rhus abyssinica* Hochst ex. Oliv.

141. *Rhus retinorrhea* Steud. ex.

142. *Rhynchelytrum repens* (Willd). Hubb.

143. *Rhynchelytrum* sp.

144. *Rhyncosia* sp.

145. *Ruellia patula* Jacq.

146. *Rumex ellenbekii* Dammer.

147. *Sageretia thea* (Obeck). M.C.Johust.

148. *Setaria pallidefusca* Stapf & Hubb.

149. *Setaria verticillata* (L) P. Beauv

150. *Senecio abyssinicus* Sch. Bip.

151. *Senecio discifolius* (Oliv).

152. *Senecio* sp.

153. *Sida alba* L.

154. *Sida ovata* Forsk.

155. *Solanum histifolium* Hochst ex. Dunal.

156. *Solanum incanum* L.

157. *Solanum nigrum* L.

158. *Solanum polyanthemum* Hochst.

159. *Solanum schimperianum* Hochst.

160. *Sporobolus festivus* Hochst ex Rich.

161. *Sporobolus panicoides* A. Rich

Appendix I (cont'd)

162. *Sporobolus Pyramidalis* P. Beav.

163. *Tagetus minuta* L.

164. *Tapinanthus globiferus* (A. Rich) Van. Tiegh.

165. *Tephrosia pumilla* Pers.

166. *Tephrosia uniflora* Pers.

167. *Tragus betronianus* Schult.

168. *Urochloa panicoides* Beav.

169. *Vernonia cinarescens* Sch. Bip.

170. *Vernonia* sp.

171. *Ximenia americana* L.

172. *Zizphus spina - christi* (L) Willd.

Appendix J

Stand and plant species present in them

Stand No.	Plant species
1	11, 46, 47, 56, 57, 66, 76, 120, 126, 143, 146.
2	11,46,47,56,57,66,76,86,143
3	33,46,47,56,57,66,76,120,126,143,146.
4	11,33,46,56,66,76,143,146,
5	11,46,47,56,57,66,76,120,126,143,146,
6	11,33,46,56,57,66,76,126,143,146.
7	11,46,47,56,57,66, 76,120,126,129,143.
8	4,21,23,46,54,56,57,58,87,90,94,103,119,139,154,169.
9	4,16,21,46,54,56,57,58,75,78,89,93,148,154,172.
10	4,34,37,42,46,50,54,56,57,58,63,76,85,90,119,131.
11	4,14,15,25,46,49,56,57,58,74,81,131,
12	8,21,46,48,56,57,58,81,85,104,106,109,115,118, 131,157,168.
13	3,4,11,27,46,56,57,58,119,160,172.
14	4,12,16,17,21,46,54,56,57,58,81,114,119,128,131, 139,146,165,172.
15	2,4,8,9,10,15,26,30,38,46,47,51,56,57,89,91,94,95, 98,102,104,105,110,116,119,133,135,148,154,166.

Appendix J (cont'd)

Stand No.	Plant species
16	1,2,3,4,5,30,31,40,45,46,52,56,57,82,100,104, 108,119,131,133,156,170,171.
17	5,22,28,30,38,46,56,57,59,68,69,70,72,76,89,90, 158.
18	3,4,22,26,41,44,46,56,57,62,64,77,119,131,156.
19	4,5,6,46,56,57,83,89,96,99,119,149,156.
20	3,4,30,41,56,57,64,73,75,77,119,145,151,167.
21	3,4,22,30,39,46,56,57,64,77,89,99,107,119,131, 138,156.
22	4,5,15,18,20,21,32,43,55,56,57,58,87,96,97,99, 101,111,112,115,116,118,119,126,129,139,150.
23	21,53,56,57,58,61,87,89,90,126,129,133,137, 163,165.
24	3,4,7,15,20,21,56,57,58,65,67,87,93,99,115,117, 119,121,125,139,163,164,165.
25	2,4,13,17,21,28,33,56,57,58,67,104,119,130,132, 134,139,140,170.
26	4,5,21,56,57,58,67,104,119,127,134,142,159,163, 165.
27	4,21,56,57,58,67,119,134,142,159,165.
28	4,56,57,58,67,119,134,142,165.

Appendix J (cont'd)

Stand No.	Plant species
29	4,5,21,46,56,57,58,68,89,104,119,131,172.
30	4,21,23,56,57,58,60,68,100,117,119,145,155,165,172.
31	4,11,21,46,56,57,58,68,80,92,104,119,153,172.
32	4,11,15,21,24,56,57,58,83,87,90,104,119,123,126,131,156.
33	4,5,14,15,21,23,36,46,56,57,58,66,68,77,90,104,172.
34	4,5,15,21,23,46,56,57,58,66,68,77,90,104,172.
35	4,5,15,21,23,46,57,58,66,68,90,104,172.
36	3,29,56,58,67,71,79,98,103,111,115,147,152.
37	3,11,15,19,48,56,58,67,71,79,93,101,115,124,131,148,161,162,168.
38	3,11,15,35,56,58,67,103,104,115,123,136.
39	3,15,19,56,58,87,98,103,104,111,113,115,121,123,141,144.
40	19,29,56,58,84,104,115,121,122,123,141.
41	21,56,58,87,100,104,113,119,141,157.
42	5,15,56,58,104,115,123,141,166.

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