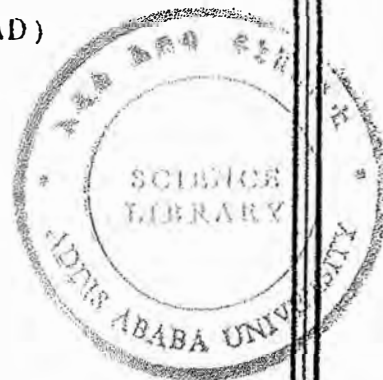


**AN ECOLOGICAL STUDY OF THE VEGETATION ON THE  
EASTERN ESCARPMENT OF ERITREA, ETHIOPIA**

(ALONG THE ASMÉRA - MITSWA ROAD)

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



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In Partial Fulfillment  
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By  
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## ABSTRACT

An ecological study of the vegetation on the Eastern Escarpment of Eritrea from an altitude of 190 meters to an altitude of 2075 meters above sea level was performed. Seventy-seven stands were selected systematically and all plants found in the stands were recorded as present. A number of environmental factors including slope, aspect, altitude and percentage of rock cover at the surface were measured. Soils sample were also taken from each stand and analysed for texture organic matter, color, conductivity, pH and the cations K, Ca, Mg, Na and Mn. The vegetation data were analysed by two-way indicator species analysis and 10 homogenous groups of stands were formed. The groups of stands were compared for their averaged environmental factors using the t-test. Rank correlation was also computed for the averages of the different environmental factor in each stand group.

The groups of stands were observed to show the highest number of contrasts in altitude. Altitude in itself does have any effect on the distribution of vegetation, but it is associated with changes in atmospheric pressure, moisture, temperature and other factors. In the study region the amount and distribution of moisture was the factor that was mostly highly associated with altitude. It can thus be said that the main cause for the variation in vegetation on the Eastern Escarpment of Eritrea was the difference in moisture. Variation

of moisture between the stands was also accompanied by variations in soil physical and chemical characteristics and topographic factors.

Ordination studies were also performed using detrended correspondence analysis, reciprocal averaging and weighted-averages ordination. The results from these studies confirmed the findings from the classification by the two-way indicator species analysis.

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## CHAPTER 1

### 1. INTRODUCTION

#### 1.1 Statement of the Problem

Historically, the Ethiopian forests represented the greatest resource in East Africa and contained the largest coniferous trees in the continent (Ruth, 1944). However, continuous and indiscriminate lumbering and felling for fuel and replacement of forest by agricultural land have left the country with very limited forest resources (Hedberg, 1979). These interferences with the natural vegetation have been proceeding at very alarming rates especially in the past few decades, and different authors have reported a constantly decreasing percentage of the forest cover of the land means: in 1954 it was 16% (Hedberg, 1979); in 1959, 5% (Mooney, 1959); in 1961 8% (Weldemicael, 1961); and in 1975 4% (Hedberg 1979). The Ministry of Agriculture has reported that at present an estimated 200,000 hectares of forests are cleared every year for agricultural use, for fuel wood and other reasons, out of which 60,000 hectares of Acacia forest alone are cleared for charcoal (Ministry of Agriculture, 1983).

These abuses of the natural vegetation have caused incalculable damage to the environment. It is now estimated that more than 50% of the land area in the country suffers from severe erosion. (Ministry of Agriculture, 1983). McDougal et. al. (1975) estimated the rate of erosion in the head waters of the Blue Nile and Tekeze to be  $120-240 \text{ m}^3 \text{ km}^{-2} \text{ yr}^{-1}$  which is more than 10 times greater than the overall geological rate. The mean rate over the past 23.5 million years is  $12-6 \text{ m}^2 / \text{km}^2 \text{ yr}$ . From the central plateau to Tigray - an area very near to the study area -  $17-33 \text{ ton/ha}$  ( $650-1245 \text{ m}^3 / \text{km}^2 / \text{yr}^{-1}$ ) of soil are eroded (Vigro and Munro, 1977).

The status of the natural vegetation in the Eritrean Administrative Regions is no exception to the general situation of the country. Before the Italian occupation, the region was reported to have had more than 30% of its land area covered by forests (Forestry Department, Asmara, 1974). In 1961, Mooney reported that no natural forests of value remained in Eritrea apart from some dry type closed forest near the foot of the Fil Fil ghat and some juniper forest near Nakfa on the northern edge of the Eritrean Escarpment.

If we consider the vegetation on the Eastern escarpment of Eritrea in particular, until quite recent times, the ragged and steep topography discouraged human interference and thus the vegetation was kept intact. However, the development and expansion of new urban centers in the region with a proportionally increasing demand of wood for fuel and construction, agricultural expansion from the Eritrean plateau eastwards down the escarpment, formation of agro-industrial centers in the region, new settlement of the pastoralists in the region and grazing by the nomads and pastoralists from the coast are currently exerting considerable pressure on the remaining natural vegetation.

This destruction of the natural vegetation of the escarpment has resulted in the exposure of the area with its steep slopes to serious erosion by wind and water as well as the loss of the water that falls on the region as rain without being properly utilized. It has also resulted in the exposure of the relatively densely populated agricultural plateau to severe dust laden desert winds which could seriously affect the subsistence cultivations operating on the plateau. Destruction of

the natural habitats of the wildlife of the region has also occurred.

## 1.2 Objective of the Study

To amend this trend of abuse and deforestation and to manage the remaining scanty vegetation on the Eastern Escarpment of Eritrea scientifically, an ecological study of the region becomes imperative. Previously, a number of workers have made ecological studies in the region. Picchi Sermoli (1957) has included the region in his geobotanical study of the Horn of Africa (Ethiopia and Somalia). Kassar (1957) and Hemming (1961) have made ecological studies of the Red Sea coastal region of Ethiopia, which included the lower portions of the escarpment. Wilson (1977) has also included the Eastern Escarpment of Tigray which is a southern continuation of the Eritrean Escarpment, in his study on the ecology of Tigray. But modern techniques of multivariate analysis were used in none of the previous studies. In this project the ecology of the vegetation from Asmara to Mitswa, which was thought to be representative of the Eastern escarpment of Eritrea, was studied.

Classification and ordination techniques were used to understand and formulate a hypothesis for the structure of the vegetation and to correlate the vegetation with some environmental factors. It is hoped that the results of the study will give some information that would suggest solutions to the problems of conservation of ecosystems in the area, and regions in northern eastern Ethiopia with similar problems.

CHAPTER 2.

2. LITERATURE REVIEW

2.1 Description of the Study Area

2.1.1 Geology and Geomorphology

Ab ul-Haggag (1961) has discussed in some detail the geology and geomorphology of the Eastern Escarpment of Eritrea in his work on the physiography of Northern Ethiopia. The region exhibits a diversified topography. From the eastern edge of the interior highlands to the 200 meters contour, the land surface falls some 2000 meters on the average and up to 3000 meters in extreme cases. The width of the escarpment varies in extent from place to place but is rarely less than 30 m. It is composed of ancient rocks of the basement complex, primarily gneisses, granites, diorites and schists.

The resistance of these rocks to the agents of erosion, mainly the powerful torrents plunging from the interior highlands to the coastal lowlands, varies greatly in short distances, thus rendering the landscape one of considerably complicated

patterns. The escarpment face on the higher parts is exceptionally steep; for instance, the road between Chinda 960 meters and the plateau edge near Asmera a direct distance of 20km makes a laborious ascent of 1500 meters through 45 km of road.

Flat areas of any significant extent are rare on the upper slopes. However, between Asmera and Mitswa lies the fairly small Ghinda plain at about 900 meters above sea level. The lower parts of the escarpment continue to be rugged though less markedly. So, here lies the most extensive flat area of the region namely the Wakiro basin, which extends from the confer wells area in the north across the Asus and Ailet plains to the Sabarguma and Damas plains in the south. These plains consist of a vast deposit of mixed sandy and stony alluvium derived from the ancient basement massif.

### 2.1.2 Climate

#### 2.1.2.1 Rainfall

The Eastern Escarpment enjoys two rainy seasons, one in the summer and one in the winter. The summer rainfall is identical to the 'Big rains' on the Ethiopian highlands as a whole (Suzuki 1967, Daniel, 1977). During the summer season, the Intertropical

convergence zone (ITCZ) runs nearly parallel to or along the Ethiopian Red Sea coast (Daniel 1977). At this time the whole of the country except the south eastern lowlands comes under the influence of the Atlantic westerlies which produce the main rainy season when ascending the mountains. In Eritrea, the summer rainfall is heaviest in the western upper slopes, decreases rapidly towards the east until it practically disappears in the coastal lowlands.

In the winter season, the ITCZ shifts to the equator. A big anticyclone is created over western Asia from where winds blow across Ethiopia to the low pressure area in central Africa. (Suzuki, 1967; Daniel, 1977). These northeasterly winds, on ascending the escarpment, release their humidity in light drizzle, and, more frequently, in the form of dense mists. Abul-Haggag (1961) reported that the higher parts of the escarpment (roughly between 800 meters and 2000 meters altitude) benefit from both the summer and winter rains in high amount. The total annual rainfall in some of these places is more than 1000 mm, with the dry season being limited to only twenty to thirty days in October and November and

thirty to forty days in May and June. At altitudes below 800 meters the total annual rainfall decreases, while the proportion of winter precipitation becomes progressively higher. Table 1 gives some rainfall data of Asmera, Ghinda and Mitswa, from which comparisons can be made with the coastal plains represented by Mitswa and the plateau represented by Asmera.

Because of the uneven topography of the region, many local irregularities, both in the total annual rainfall and in the seasonal distribution of rainfall are observed. The form of the slope, the height of the overlooking summits and the width and form of the valleys are some of the factors additional to altitude that control rainfall distribution in the region (Abdul-Haggag, 1961). For instance, while Merrara, 2390 meters above sea level receives an annual rainfall less than 1000 mm Fil-Fil, some 800 meters above sea level, receives about 1300 mm, the latter locality lying on a sea word facing position and thus benefiting from a much greater quantity of winter precipitation than Merrara, which is less open towards the east. Again, the Mai Hinzi valley between the Asmera plateau and

Mt. Bizen receives relatively small and exceptionally irregular rains since the winter air streams in particular arrive there after having released a greater proportion of their moisture on the high mountain ranges of Mt. Bizen.

#### 2.1.2.2 Temperature

With the diversified topography of the land surface, variations in temperature from place to place are highly pronounced. Abul-Haggag (1961) estimated that between Mitswa and Asmera temperature decreases by about 0.495 for every hundred meters rise, this being only 0.450°C for every 100 meters rise between Asmera and Ghinda.

A general impression of the temperature regime on the escarpment may be gained from the figures for Ghinda which lies at a medium elevation (960 meters above sea level). The mean annual temperature is 24.2°C, with the means of the coldest month (January) and the warmest month (July) being 18.3°C and 29.4°C respectively. The mean daily range is about 8°C.

Tables 2 and 3 gives some temperature data for Asmera, Ghinda and Mitswa, from which comparisons

Table 1: Rainfall - monthly means of Asmera, Ghinda and Asmera (mm)

	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Total	Altitude in meters
Mitswa	17.6	18.2	10.4	1.5	3.5	0.9	0.3	8.8	7.0	35.0	13.0	13.0	129.2	2
Ghinda	73.7	118.8	92.7	45.6	37.3	6.9	85.6	49.0	21.2	37.3	58.1	58.1	684.3	962
Asmera	6.3	1.1	17.0	48.9	46.0	48.3	248.6	191.3	24.5	22.6	22.6	11.3	688.5	2372

Source: Meterological Station of Asmera, ERitrea, Ethiopia (The values are averages for 10 years)

Table 2: Temperature - monthly means of Asmera Ghinda and Mitswa ( $^{\circ}$ C)

	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec	Altitude in meters
Mitswa	25.6	26.0	27.2	29.0	31.3	33.5	34.8	34.7	33.3	31.7	29.9	30.3	2
Ghinda	18.3	19.6	20.5	24.0	26.9	29.4	28.1	28.1	28.3	24.9	22.0	20.2	962
Asmera	17.2	18.1	119.2	19.7	19.0	18.1	18.1	17.6	17.5	16.8	16.8	15.3	2372

Source: Abul-Haggag (1961).

Table 3: Temperature - ranges and other means of Asmera, Ghinda and Mitswa ( $^{\circ}$ C)

	Mean annual	Mean of warmest month	Mean of coolest month	Mean annual range	Mean daily range	Absolute maximum	Absolute minimum	Altitude in meters
Mitswa	30.6	34.8	25.6	9.2	6.9	44.5	18.5	2
Ghinda	24.2	29.4	18.3	11.1	8.0	37.5	12.0	962
Asmera	17.8	19.7	16.8	2.9	12.3	29.5	2.7	2372

Source: Abul-Haggag (1961).

can be made with the coastal plains represented by Mitswa, and the plateau represented by Asmera.

### 2.1.3 Vegetation

Picchi sermoli (1957) classified the vegetation on the eastern escarpment and the coastal plains into six types: the desert, the subdesert scrub, the subdesert succulent scrub, the xerophyllous wood land and the montane evergreen thicket and scrub.

The montane ever green thicket and scrub in Tigray, south, of the study area, occurs along higher slopes from an altitude of about 1000 meters to the crest (Wilson, 1977). Two variants of this type of vegetation can be recognized. One variant consists of Euphorbia abyssinica dominated vegetation, which is usually found on shallow soils and rocky outcrops of the regions where winter rainfall is relatively scarce and the main rainy season is summer. The other variant contains a variety of species in several genera including Carrisa, Euclea, Rhus, Maytenus, Dodonala, Buddleja, Olea and Juniperus. According to Wilson (1977) Dodonala viscosa and Euclea schimperii have no apparent ecological limitations

although *D. viscosa* survives better at slightly lower altitude and *E. schimperi* is best suited to limestone soils.

At altitudes between 500 meters and 1200 meters in valleys and gorges, typical associations of the sub-desert succulent scrub occur. The main constituents are Dracaena, Euphorbia, Aloe, Sanseveria, Adenia and Caralluma.

The sub-desert scrub, according to Wilson (1977) runs in a strip along the lower slopes of the escarpment varying in altitude between 200 meters and 1500 meters. The typical genera found in this association are Acacia, Zizyphus Maerua, Cadaba and Boscia with a number of succulents.

In the lower plains of the escarpment are found in the xerophyllous open woodlands. These woodlands consist of short-stemmed, multibranched, conical shrubs of about 3.5 meters tall, which sometimes form small thickets, and the scattered umbrella shaped trees upto 8 meters in height (Breitenbach, 1961). The typical trees are Acacia tortilis, and other Acacia spp, Balanites aegyptica (especially near the foot of the escarpment) Dobera glabra and Adansonia digitata on rocky outcrops

(Wilson 1977). The open areas between the shrubs and trees are dotted with tufts of perennial grasses, e.g. Conchrus ciliaris, leaving spots of bare soil covered with annual grasses and other herbs, e.g. Dactyloctenium aegypticum, Sporobolus pellucidus, Kyllinga nuicrostyla, Cyperus teneriffae and Courtoise sp only after the rains (Breitenbach, 1961; Hemming, 1961).

#### 2.1.4 Human Settlement

With its rough topography, humid and malaria infested conditions, the eastern escarpment in the past was very sparsely populated, permanent settlements being limited to a few scattered villages (Abul-Haggag, 1961).

The writer has observed that seasonal cultivators from the Eritrean plateau move into the Eastern Escarpment in the winter season. They plant mainly maize, tef and finger and pearl millets. During the summer they move up to the plateau.

Pastoral people, the saho, also exhibit a migratory habit between the plateau and the escarpment. These people live on the escarpment from November to April. From May to June they move up

the slopes to the edges of the Plateau, which are then covered by rich vegetation. When the rainy season on the plateau is at its height, they move up the plateau itself, to descent later to their winter grazing grounds. During their stay on the escarpment, they engage in some agriculture, planting maize, and finger and pearl millets.

In the last few decades a number of extensive farms like the Ghinda orchards and the farms in Ala, solomona and Merrara have also been established.

## 2.2 Sampling Methods in Community Ecology Studies

Community sampling in the initial, observational phase in community studies. The inherent strength or weakness of a study and the range of potential data analysis that will be subsequently appropriate are determined and fixed to a great degree at the first step, data collection. One has then to carefully consider the community sampling procedure one should choose and the corroborative environmental and historical data he should gather. Several texts include substantial treatment on community sampling methods for a variety of vegetation types. Greig-smith (1964), Shimwell (1971), Mueller Dombois and

Ellenberg (1974), Kershaw (1980) and Gauch (1982) are some of the texts that deal with this topic.

Although there are uncountable possibilities for sampling procedures, they all have with a few exceptions one or other of the three objectives defined by Greig-smith (1964).

- a) Estimation of the overall composition of the vegetation of an area, with a view to comparison with other areas or with the same area at another time.
- b) Investigation of variation within the area.
- c) Correlation of differences in vegetation with differences in one or more habitant factors.

Homogeneity is regarded by most phytosociological schools as the first important feature to be taken into consideration in the choice of a sample stand for description (Shimwell, 1971). Community samples should be homogeneous in structure and composition if the research purpose is to represent community type by sample or to relate vegetation to environment. Samples should also be of uniform environment (without apparent differences of soil type, moisture status,

and distribution) in order to allow comparisons of vegetation and environment and to avoid differences in the vegetation the environmental non-uniformity ordinarily imposes (Gauch, 1982).

Samples may be placed in a study region by four methods: 1) random location 2) regular placement in a grid transect 3) preferential selection of sites considered especially typical, homogeneous, representative or undisturbed and 4) stratified sampling in which the study region is subdivided into compartments by some criteria and each compartment is then sampled using random sampling.

Systemic sampling is the method most frequently used by ecologists. Compared to random sampling, errors introduced by the ecologists biased preconception and invalidity to statistical tests puts the method to a disadvantage. Nevertheless, the method is indicated to be entirely adequate for studies that employ multivariate statistical analysis to describe a community (Gauch, 1982); and in some cases, as where variation in the community is nearest to continuous, the technique has been even found to be more accurate than random sampling (Geig-smith, 1964; Green, 1979; Gauch, 1982).

Placement of sample stands may be a major problem in data collection processes, but even when this has been satisfactorily resolved there still remains the difficulty of deciding the size and shape of the quadrat, and the number of samples.

Several considerations affect sample size determinations. A sample should be large enough to represent effectively the species present in the community, and if quantitative data are taken, large enough for a reasonably reliable estimate of the species abundance (Gauch, 1977). Plants and animals are hardly distributed at random in nature. Rather, they are patterned on scales of several sizes and likewise, the environment is patterned on several scales. Consequently any sample size will be appropriate for some species and environmental factor, too small to be representative for others and too large to be homogenous for yet others (Gauch, 1982). Two relatively objective methods for selecting sample size have been developed: 1) species area curves that plot the increase in species number against sample size and 2) measurement of dispersion for sets of replicate samples from a given community (Greig Smith, 1964; Shim-

well, 1971; Mueller-Dombois and Ellenberg, 1974; Guch, 1977; and Guch, 1982).

Westoff and Maarel (in Gauch, 1982) suggest various sample sizes for various kinds of vegetation: Temperate sclerophyll shrubland, 10-100 m<sup>2</sup>, weed communities 25-100 m<sup>2</sup>; temperate deciduous forest 100-500 m<sup>2</sup>; mixed deciduous forest 100-500 m<sup>2</sup>, and tropical rainforest 200-1000 m<sup>2</sup>. American scientists have found 0.1 hectare (20 x 50 m) size suitable for forests, woodland, grassland and desert samples. Tewoldeberhan (1974); Sebsebe (1981), and Hailu (1982) have used 400 m<sup>2</sup> (20 x 20 m) stands for woody vegetation with good results in Ethiopia. This same size (20 x 20 m) was adopted in this study.

Quadrat shape by tradition is square. However, one of the errors introduced by quadrat shape edge effect, is slightly reduced if the perimeter is reduced relative to the area, and this can be (Goldsmith and Harrison, 1976) achieved by using round quadrats. Clapham, 1932 (in Goldsmith and Harrison, 1976) advocates the use of rectangular quadrats, oriented parallel to the principal gradients of variation in vegetation although edge effect increases with length:

breadth ration. Gauch (1982) considers a rectangle that is 2-4 times as long as it is wide to be most accurate. Nevertheless, the difference that would be obtained with various shaped quadrats is reported to be very small (Goldsmith and Harrison, 1976).

When considering the number of sample units one should adopt the general rule of the more the better (Goldsmith and Harrison (1976). However, the objective of sampling, as opposed to recording everything, is to reduce the amount of labour and time involved, the actual number to be used is therefore, a compromise between an ideal number, which is quite large, and a number which would not take much time to collect (Gauch, 1977).

Whittaker (1978), in Gauch (1982) gives three recommendations for selecting the number of samples in a community study. 1) Along a well defined gradient of vegetation and environment relatively few samples, 5-20, are taken at fixed intervals such as elevation up a mountain. 2) In a substantially disturbed landscape typically 50-100 samples from all or many sites of sufficiently large, undisturbed, homogeneous vegetation may suffice. 3) In an area of complex environmental variations sample

are taken at frequent but unspecified intervals as the investigator encounters new combinations of community composition and environment. For example, for each 300 meters elevation belt on a given parent material in mountains, 50-60 samples is recommended.

### 2.3 Methods of Analysing Vegetation Data

Plant communities involve many species and environmental factors with complex relationships. A wide variety of multivariate methods are employed to study the complex nature of communities, with the general objective of summarizing large complex data sets obtained from community samples, aiding in the interpretation of the data and the generation of hypotheses about community structure and variation.

Gauch (1982) categorized these multivariate analyses into three basic strategies direct gradient analysis, ordination and classification.

Direct gradient analysis is used to display the distribution of species along recognizable, easily measured, environmental gradients (Whittaker 1967). It provides the primary observational basis for ecological models of community structure

and relatively well understood field data sets which are then appropriate for testing multivariate methods because the expected results are known to a fair degree (Gauch, 1982).

Classification and ordination strategies originally emanated from the two theories concerning the nature of vegetation, the community concept and the continuum concept (Whittaker, 1962; MacIntosh, 1967; Greig-smith, 1964; Kershaw, 1980; Pielou, 1977). The proponents of the community concept maintain that there exist considerable interrelationships among the species of a community which, in growing together, sufficiently modify an environment to form a recognizable and repetitive vegetational grouping. Conversely, the proponents of the continuum concept maintain that no two communities are strictly identical but rather that communities exhibit continuous variations in their detailed composition and therefore cannot be readily delimited as clear cut units.

Any procedure of vegetational classification involves an arrangement of communities into classes, the members of each class having in common a constellation of attributes which serve to set them

apart from members of other classes. Implicit in this approach is the belief that there is some discontinuity in species composition among concrete samples of vegetation in the field as well as among theoretical units abstracted from such field data.

The concept of ordination is based on the premise that there are no such discontinuities in natural vegetation, except where there may be discontinuities in the physical environment. The process of ordination involves an attempt to place each stand of vegetation in relation to one or more axes in such a way that a statement of its position on such axes conveys the maximal amount of information about its position.

At present the Gaussian model of community structure implying continuous community variation is generally accepted, making ordination somewhat natural (Pielou, 1977; Greig-smith, 1980; Gauch, 1982). Eventhen, classification can be used to condense and simplify a mass of field observation (e.g. Kershaw, 1968; Greig-smith, 1967; Shimwell, 1971; Pielou, 1977; Gauch, 1982), and if obvious clear-cut vegetational discontinuities do occur in nature, ordination can be used as an aid to under-

standing the relation of the groups identified to one another and the environment with the groups (Pielou, 1977; Maarel, 1979). Thus it is now generally accepted that the choice between classification and ordination depends on the objective of data analysis and the structure of the data set being examined, rather than on preconceptions about the nature of the vegetation (Greig-smith, 1980). Many workers have been advocating for an integrated use of the complementary classification and ordination techniques. Greig-smith et.al. (1967) suggest classification of the data sets to precede ordination in order to ensure homogeneity of the groups being ordinated and make interpretation simpler. Hill (1973) however, prefers ordination to precede classification because an overall view of the structure of the data, which can be used as a basis for classification, can be obtained from preliminary ordination. Pielou (1977) in agreement with Hill (1973) suggests for the ordination to precede classification and indicates that after the classification has been done, the interrelations of the resultant clusters can be portrayed and examined by again ordinating the cluster centers.

### 2.3.1 Classification

Extensive treatment of techniques of community classification have been given by Shimwell (1971), Mueller-Dombois and Ellenberg (1974), Whittaker (1978) and Gauch (1982). Its early history has been covered by Whittaker (1962).

The main classification techniques in community ecology may be categorized in three groups; viz, those that have table arrangements, non-hierarchical classification, and hierarchical classifications (Gauch, 1982).

Maarel (1979) has given the details of table arrangements. Table arrangement is the earliest classification technique in community ecology (Gauch, 1982). It has a unique advantage in that it displays at once both the full detail of the data set and the general features. The Braun-Blanquet table arrangement seeks to order the samples-by-species data matrix into the order that best reveals the intrinsic structure of the data. Compositionally similar samples are brought together as are distributionally similar species. The non-zero data matrix entries are thereby concentrated into blocks, and lines may be drawn in

the matrix to mark off sample and species clusters.

Gauch (1982) described the Braun-Blanquet Table-work as an informal, fairly subjective method. It is a polythetic, hierarchial dual classification. Recently computers have overcome some of the limitation of the system, by introducing objectivity, reducing tedious labour, and reducing the requirement of expertize. TABORD is one of the advanced computer programs for Braun-Blanquet table-work (Maarel, 1979; Gauch, 1982).

Non-hierarchical classification is conceptually the simplest of all multivariate classificatory analyses. It merely assigns each sample (or species) to a cluster placing similar samples (or species) together (Gauch, 1980; Gauch, 1982). The structure of the individual groups is optimized since these are made as homogenous as possible. No route is defined between groups and their constituent individuals so that the infrastructure of a group cannot be examined. Similarly no routes can be defined between groups and the complete population (Williams, 1972).

Gauch (1980) has used non-hierarchical classification for rapid initial clustering of large data

sets. He indicated that such clustering mitigates noise, identifies outliers and summarizes redundancy. It does not elucidate relationships but can produce fewer composite samples, which could easily be analysed for their relationships by other multivariate methods. Gauch (1979) has developed a computer programme COMPLUS for this rapid initial clustering.

Hierarchical classification groups similar entities together into classes as does non-hierarchical classification, but additionally, it arranges these classes into a hierarchy. It optimizes a route between the entire population and the set of individuals of which it is composed. The route may be defined by progressive fusions, beginning with the individuals and ending with the complete population, an agglomerative strategy; or by progressive divisions, beginning with the population and decomposing it into subgroups and, if need be, into individuals, a divisive strategy. Divisive techniques have two advantages over agglomerative ones.

- 1) Their computations are generally much quicker, since it usually is not necessary to subdivide down to the point at which individual quadrats are recognized as classes. When an agglomera-

tive methods is used we must begin with individual quadrats so that if there are  $n$  individuals this requires the calculation appropriate to at least  $(n-1)^2$  fusion (Williams, 1971; Greig-smith, 1980) and if  $n$  is large this may require an unacceptably long computation.

- 2) Divisive methods use all available information at the initial stage and are less likely to be irrevocably led astray by chance (Noy-meir, 1973; Williams, 1971; Pielou, 1977; Greig-smith, 1980; Gauch, 1982).

Classification can also be monothetic or polythetic. A monothetic division is one based on a single attribute such that the population will be divided into those that do and those that do not possess the attribute. A polythetic system, in contrast, is one based on a measure of similarity or dissimilarity applied over all attributes, so that an individual is grouped with those individuals which on the average it must resemble.

Compared to polythetic classifications, monothetic methods have the advantage of speed, simplicity and clarity of sub-group definitions (Williams, 1971; Greig-smith, 1980; Everitt, 1980). Neverthe-

less, they are liable to a trouble some form of misclassification (Williams, 1971; Hill, 1975; Everitt, 1980; Gauch, 1982). Thus it logically follows that divisive polythetic systems are the best hierarchical systems (Williams, 1972; Greigal and Goldstain, 1971; Noy Meir, 1973; Hill et.al., 1975; Gauch and Whittaker, 1981).

A technique that combines the preferred characters, namely hierarchical, divisive, and polythetic is the indicator species analysis developed by Hill, Bunce and Shaw in 1975. The technique first ordines the data by reciprocal averaging, then these species that characterize the reciprocal averaging axis extremes are emphasized in order to polarize the samples, and the samples are divided into two clusters by breaking the ordination axis near its middle. The division process is then repeated on the two sample subsets to give four clusters and so on until each cluster has not more than a chosen minimum number of members. Hill (1979) improved the technique to perform classification of stands and nominated the technique as two-way species-indicator analysis. The two classifications are then used together to obtain an ordered two-way table.

### 2.3.2 Ordination

Ecologists use quite a big array of ordination techniques, some of the popular ones being weighted averages, polar ordination, principal component analysis, reciprocal averaging, detrended correspondence analysis and non-metric multi-dimensional scaling.

Weighted averages ordination is among the earliest and simple ordination technique used. It was developed independently by Ellenberg (1948), Whittaker (1948), and Curtis and McIntosh (1951). Weighted averages produce sample ordination scores from an ecologists previous knowledge of the species or species ordination from previous knowledge of the samples. For example, if  $A_{ij}$  is the abundance of species  $i$  in sample  $j$  of a sample-by-species data matrix and  $W_i$  is the weight of species  $i$ , weighted average algorithm computes an ordination score  $S_i$  for each sample  $j$  such that

$$S_i = \frac{\sum A_{ij} W_i}{\sum A_j}$$

where the summation are over all species:

Weighted averages ordination customarily incorporated environmental or ecological gradients

relatively directly. Usually the species weights (or sample weights) reflects successional status, moisture conditions, or any other concrete ecological gradient (Gauch, 1982).

Bray and Curtis (1957) devised an ordination technique that has been used much in plant ecology. In the technique, two samples serve a special role as poles of an ordination axis, so that the technique is commonly called polar ordination.

The Bray and Curtis ordination method used the coefficient of similarity  $C = \frac{2w}{a+b}$ , where  $a$  and  $b$  are quantities of all plants found in the two stands to be compared and  $w$  is the sum of the smaller value of these species common to the two stands. The resultant coefficients are placed in a matrix and the least similar stands are chosen as end points of a gradient on which the other stands are placed according to their relative similarities to the polar stands. A relatively objective ordination technique which requires no subjective choice of points or weights is principal component analysis. Principal component analysis was originally developed by Pearson in 1901 and later by Hotelling in 1953 for psychological analysis, and was first used in

ecological studies by Goodall in 1954 (Dale, 1975; Gauch, 1982). Principal component analysis involves two distinct stages: an initial transformation of the data and the extraction of the eigen values and eigen vectors of the matrix of cross products between the transformed data. The transformation may involve either or both centering and some form of standardization (Orloci, 1966; Gittins, 1969; Dale, 1975; Gauch, 1977; Greig-smith, 1981; Gauch, 1982). Ordination of both species and stands are obtain in a single analysis.

Reciprocal averaging, a technique related both to weighted averages and to the principal components analysis and other eigen vector analyses (Hill, 1973; Gauch, 1977; Gauch, 1982) became a very important method after Hills introduction of the technique in 1973. A number of other names have assigned to the technique; e.g. correspondence analysis by Benzeri, 1969; reciprocal ordering by Orloci, 1978; and dual scaling by Nistusato, 1980 (in Gauch, 1982).

Reciprocal average is generally used to reveal correspondence among number of observations, between two kinds of information such as species and samples.

Hill (1973) describes the method as a weighted averages ordination effected by successive approximations. In its direct iteration algorithm (Hill, 1973, Appendix 2) species are weighted by portions along a rough initial gradient and the weights are used to calculate the sample scores. These sample scores as weights are then used to calculate a new and improved calibration of species. The new species weights provide further improvement in sample calibration. Back and forth iterative calculations leads to a stable solution that does not depend on the initial weights.

Reciprocal averaging has two major faults, both of which hinder interpretation of results. First, the second axis may be merely a quadratic distortion of the first axis - the arch effect or the horse shoe effect (Hill, 1973; Gauch, Whittaker and Wentworth, 1977; Hill and Gauch, 1980; Gauch, 1982). The arch effect persists to many dimensions, the third axis being a cubic distortion, the fourth a quadratic and so on (Gauch et. al., 1977).

The second main fault of reciprocal averaging is its failure to preserve ecological distances. Sample pairs with equivalent compositional distances

appear further apart in the middle than towards the ends of the first axis.

Detrended correspondence analysis, a development of reciprocal averaging, corrects the two major draw backs of reciprocal averaging (Hill, 1979b; Hill and Gauch, 1981). The arch distortion of reciprocal averaging arises because the second axis of reciprocal averaging is constrained to be uncorrelated with the first axis, but is in no way constrained to be independent of it (Hill, 1979b; Hill and Gauch, 1981). For the axes to be separately interpretable, they need to be independent not merely uncorrelated.

The orthogonality criterion for the second and higher axes of reciprocal averaging is replaced in detrended correspondence analysis with the stronger criterion that the second and higher axes have no systematic relation of any kind to lower axes (Gauch, 1982). In detrending, the first axis is divided into a number of segments, and within each segment, the values on axis 2 are adjusted by centering them on the average of zero. (Hill, 1979b; Hill and Gauch, 1981). Detrending is applied to the samples scores, at each iteration except that

once convergence is reached, the final scores are derived using the weighted averages of the species scores without detrending (Gauch, 1982).

Most ordination algorithms analyse a secondary matrix of similarity or dissimilarity coefficient between all pairs of samples and produce a map in which inter-point distances are suitably related to them by a scaling method (Prentice, 1977). They then approximate a linear relationship between output distances and the input similarity (or dissimilarity) coefficients (Anderson, 1971; Prentice, 1977; Gauch et.al., 1974; Fasham, 1978; Gauch et.al., 1981).

Non-metric ordination techniques replace the strong and problematic assumption of linearity with a weaker and less problematic monotonicity. They only use the rank order information in a dissimilarity matrix rather than its matrix information (Gauch, 1982).

Two forms of non-metric ordination techniques have received substantial attention from ecologists (Fasham, 1978; Gauch et.al., 1981; Gauch, 1982):

- 1) Parametric mapping which attempts to place samples in an ordination space such that the

- the response curves of the species to the new axes are as smooth or continuous as possible.
- 2) Non-metric multidimensional scaling, whose goal is to locate samples or species in a low dimensional ordination space in such a manner that the interpoint distances in the ordination have the same rank order as the sample dissimilarities or species by species dissimilarities to as a great degree as possible.

Other less familiar techniques include Factor analysis, which is similar to principal component analysis but tries to account for correlations between variables that are of interest as reflecting putative underlying causes or factors unlike principal component analysis which tries to account for as much of the total variance as possible; canonical correlation analysis which is an eigen analysis technique that tries to find ordination axes that maximally reveal the joint structure of a sample-by-species matrix and sample-by-environmental factor matrix (Austin, 1962; Gauch, 1982), and Gaussian ordination which arranges samples along a single ordination axis which maximizes the least square fit of each species's abundance values to a

Gaussian curve (Gauch, Chase and Whittaker, 1974; Gauch, 1982).

#### 2.3.2.1 Choice of Ordination Technique

Much research has been carried out to evaluate the various ordination techniques (e.g. Beals, 1973; Gauch et.al., 1977; Gauch et.al., 1981) and it was found that several data sets properties, including beta diversity, gradients, sample errors, sample cluster, outlier, disjunction and species amplitudes, and sample equilability, affect the relative performance of various ordination techniques (Gauch, 1977; Gauch et.al., 1977).

Gauch et.al. (1981) comparing reciprocal averaging, principal components analysis, factor analysis, canonical correlation, polar ordination, non-metric multidimensional and detrended correspondence reached the following set of conclusions:

- a) Reciprocal averaging is generally tolerant of curvilinearity of ecological data, while principal component analysis (Swan, 1974), factor analysis and canonical analysis are not. Its results are generally better than polar ordination.

- b) Better results than reciprocal averaging can be obtained by Gaussian ordination (Gauch et.al., 1974) for one axis coenocline only, and detrended correspondence analysis.
- c) For data sets with several directions of compositional differences, detrended correspondence analysis seems to be preferable to non-metric multidimensional scaling. Polar ordination is also reported to give better results than principal components analysis, in spite of the objectivity of principal components analysis, because the latter is mathematically inappropriate to deal with curvilinear and nonmonotonic relations with which the ecologist often deals (Beals, 1973; Gauch et.al., 1977).

These findings are useful in selecting the ordination techniques most likely to perform well under certain conditions. Nevertheless, the use of several ordinations instead of one (even the best one) is the generally accepted norm (Shimwell, 1971; Gauch et.al., 1977; Greig-smith, 1981). Gauch (1977) gives three reasons to justify the use of several ordinations:

- a) Different ordinations tend to highlight different

aspects of the data, or to serve complementary roles during the successive refinement which typifies the ordination work. Some results may be so poor that they contribute nothing, but ordinarily several ordinations will be useful.

- b) Frequently the properties of a data set are poorly known at the outset, so that general knowledge of ordination performance cannot be applied to the case at hand. Application of several ordination methods is then the safest approach.
- c) The cost of additional ordinations is usually very small when there are several programmed ordination techniques.

CHAPTER 3

3. MATERIALS AND METHODS

3.1 Location of the Study Area

The area studied is in Eritrea Administrative Region, along the Asmera to Mitswa road, from about 16 km east of Asmera to about 83 km from Asmera (32 km to the west of Mitswa). For details of the study area see the map. Fig. I in the pocket on the back cover.

3.2 Vegetation Sampling

After a preliminary survey of the region ten sites, one at every 200 meters altitudinal interval starting from sea level, were identified and from 6-9 homogeneous 20x20 meter stands were systematically selected from each site. For approximate location of the stands see Fig. 1.

During November 12-30, 1982, and January 1 - March 3, 1983, the plants found in each stand were recorded as present and unless identified without doubt, were collected and numbered for laboratory identification. Most of the specimens were then identified by comparing them with identified specimens in the National Herbarium in Addis Ababa Univer-

sity, and by referring to various Floras on the plants of Ethiopia, the Sudan, and East Tropical Africa. A list of the most commonly found and collected species with the stands in which they were found is given in Appendix A. Species which only occurred once during sampling and which could not be identified to the specific level have been omitted.

### 3.3 Environmental Data

For every stand selected a number of environmental parameters were measured. Altitude was measured using an Everest Altimeter of Thommer-Switzerland, slope was measured using Sunnto optical reading clinometer, and Aspect was determined using a Prismatic compass of Breithaupt Kassal. The values of altitude, aspect and slope for each stand is given in Appendix B1. From the corners and center of each stand, soil samples were collected from the surface up to 70 cm depth at 10 cm intervals, unless the presence of hard rock prevented this. The samples from each depth of the stand were then mixed thoroughly to a single composite sample. These were then air dried and passed through a 2 mm sieve. Percentage of rock cover on the surface was also visually approximated for each stand and the values for each stand is given in Appendix B1.

### 3.3.1 Soil Analysis

Following the procedures given by Jackson (1958), Wilde et.al. (1978) and Juo (1978), PH, conductivity, exchangeable cations, texture, organic carbon and color of the 2 mm sieved, air-dried soil samples were determined.

#### 3.3.1.1 PH and Conductivity

PH and conductivity of the soil samples were measured following the procedure given by Juo (1978). A 1:1 soil suspension in water was first made by mixing 40 ml of soil with 40 ml of distilled water. The suspension was allowed to stand for one hour, with occasional stirring. The electrode of the pH meter was then inserted into the suspension to measure the pH. Similarly, the electrode of the conductimeter was inserted into the same soil suspension to measure conductivity. The values of pH conductivity obtained are given in Appendix B6 and B7. Beckman Chemmate pH meter and a Philip Harris conductivity meter were used.

#### 3.3.1.2 Soil Texture

The Bouyoucos hydrometer method given by Juo (1978) and Wilde et.al. (1978) was used to determine

the sand, silt and clay fractions of the soil samples. Fifty-one grams of 2 mm sieved air-dried soil sample were added to 50 ml of 5% sodium hexametaphosphate along with 100 ml of distilled water. The suspension was stirred for mixing and then allowed to slake for 30 minutes in an electric powder-shaker and transferred to a measuring cylinder marked to 1130 cc. With the hydrometer in the suspension the cylinder was filled to the 1130 cc mark with distilled water. The hydrometer was then removed and the cylinder, with its top covered by hand, was inverted several times until all soil was in suspension. The cylinder was placed on a table and the time was noted immediately. At the end of 40 seconds and 3 hours hydrometer and temperature readings were taken. Results were corrected to a temperature of 67°F and for every 1°F above or below 67°F, 0.2 gradient of the hydrometer reading were added or subtracted from the reading. For calculation of percentage of different particles, the corrected hydrometer reading was divided by the amount of oven dry soil and multiplied by 100 (Wilde et.al., 1979).

The reading at 40 second measured the percentage of silt and clay in suspension. This amount subtracted from 100 gave the content of sand particles.

The second reading gave the percentage of clay in suspension. The percentage of silt was obtained by subtracting the combined percentages of clay and sand from one hundred. The results of the study are given in Appendix B2 - B4.

### 3.3.1.3 Organic Carbon

Determination of organic carbon was according to the Walk-Black method given by Jou (1978). Air-dried soil samples sieved through a 0.6 mm mesh were weighed out and placed in a 250 ml flask. The weights used were 1.00 g when organic carbon content was above 1%; and 2.00 g when it was less than 1%. Ten ml of 1 N  $K_2Cr_2O_7$  was added to the flask which was then swirled gently to disperse the soil in the solution. Twenty ml of concentrated sulfuric acid were then added to the suspension and the flask was swirled first gently to mix the soil and reagent and then more vigorously for one minute. This was then allowed to stand for 30 minutes; 100 ml of distilled water and 4 drops of 0.0025 of O-phenanthroline ferrous sulphate complex solution (ferroin) were added, and the solution was titrated with 0.5 N ferrous sulphate solution. Blank titration was also carried out to standardize the dichromate solution.

The percentage of organic carbon was then calculated according to the following formula given by Juo (1978).

$$\% \text{ organic carbon in soil} = \frac{(\text{meq } K_2Cr_2O_7 - \text{meq } SO_4) \times 0.003 \times 100 \times (f)}{\text{gram of air dry soil}}$$

Correction factor  $f = 1.33$ .

% of organic matter in soil = % of organic carbon  $\times 1.723$ .

The results are given in Appendix B8.

This method has a drawback in that the presence of a high content of ferrous-iron or manganese may contribute to the reduction of chromic acid and thus distort the results. However, it is reported to be a more rapid and accurate method when compared to other methods like the ignition or the colorimetric methods (wilde et.al., 1978)

#### 3.3.1.4 Exchangeable Cations

Cations are commonly extracted by IN  $NH_4OAC$  or Morgan's reagent 10%  $NaOAC$  in 30%  $HAC$ . The use of IN  $NH_4OAC$  is described to be the best method for extracting both mineral salts and organic matter (Allen, et.al., 1976) and was thus adopted in this study. For the best extraction of cations, the ratio of the extractant to soil is also important. If the proportion of soil is too high the reabsorp-

tion of the released nutrients becomes significant. If the proportion of the extractant is too high then the quantities extracted may become too low for satisfactory measurement. Allen et.al. (1976) suggest a ratio of about 25:1 for air dried soils and 10:1 for fresh soils. The procedure used in this study, which is according to Jou (1978) uses a ratio of 20:1. In the procedure 5 gms of 2 mm sieved air-dried soil sample were added to 30 ml of IN  $\text{NH}_4\text{OAC}$  in a 100 ml erlenmyer flask and were shaken for 2 hours. The mixture was centrifuged at 2000 r.p.m. for 5 minutes and the supernatant liquid then was decanted into another 100 ml erlenmyer flask. Thirty ml of IN  $\text{NH}_4\text{OAC}$  solution was again added to the residue and was shaken for 30 minutes. The suspension was centrifuged and the supernatant liquid was transferred into the the same volumetric flask. Another 30 ml of IN  $\text{NH}_4\text{OAC}$  was added to the residue and the procedure repeated. The extract was then filtered and diluted to 100 ml. Determination of K and Na in the extract was done on a Klinka flame photometer and Ca, Mg and Mn on a varian Tectron AA6 Atomic Absorption Spectrophotometer. To eliminate the interference from aluminium and phosphate in solution in the determination

of Ca and Mg,  $\text{La}_2\text{O}_3$  was added to 1% level. The results of the analysis are given in Appendix B9-B13. The system is, however, reported to have some disadvantages with regard to saline and alkaline soils (United States Salinity Laboratory Staff, 1954). Some saline and alkaline soils fix appreciable amounts of ammonium as well as potassium ions under moist conditions, so that values obtained for cation exchange capacity by ammonium saturation are low by amounts equal to the quantity of ammonium fixed. Moreover, high pH extracting solution typically pH  $\text{NH}_4\text{OAC}$  are recommended for calcareous soils to minimize the dissolution of calcium carbonate (Allen et.al, 1976).

#### 3.3.1.5 Soil Color

Color of soils when dry were determined using the standard Munsell color charts of 1975 edition. The results are given in Appendix 5.

### 3.4 Statistical Techniques Used in Analysis of Data

#### 3.4.1 Classification Technique

Two-way indicator species analysis, which is a recommended technique for its robustness and effectiveness (Gauch and Whittaker, 1981; Gauch, 1982) was used to classify the vegetation data. The

computer program used was the TWINSPAN program CEP-4 in the Cornell Ecology Program series and the computer used in the analysis was NCR-CRITERION V-8555M.

In the analysis of the data the default values 5 for minimum group size, 7 for maximum number of indicators and 6 for the maximum level of division, were used.

Classification of the vegetation data by association analysis of Williams and Lambert (1959 and 1960) was also tried. Although the technique is reported to give misclassification (Hill et.al., 1975; Gauch, 1982), it is also reported to have given reasonably good results when interpreted with caution (e.g. Kershaw, 1967; Greig Smith et.al., 1967; Tewoldeberhan, 1969 and 1975; Noy meir et.al., 1973; Sebsebie, 1981; Hailu, 1982). Thus it was thought that association analysis could be used to compare with the results of two-way indicator species analysis. With and without Yate's correction were the association parameters used to maximize division.

Prior to analysis of the data by both techniques of classification, species with frequency less than 5% were removed from the data matrix. This was primarily to reduce the amount of data in the computer.

Moreover, the incidence of the low frequency species could be too few to be ecologically meaningful but create problems in the interpretation of the results (Gauch, 1977; Gauch and Sing, 1982; Gauch, 1982).

#### 3.4.2 Ordination Techniques

The detrended correspondence analysis and reciprocal averaging from the DECORANA program CEP-25B in the Cornell Ecology Program series and the weighted averages ordinations from the ORDIFLEX program CEP-25B in the Cornell Ecology Program series were the ordination techniques that were used in the study. The computer used in the analysis was NCR-CRITERION V-8555N.

When analysing the data by detrended correspondence analysis, the axes were rescaled 4 times, the rescaling threshold being zero, and 26 segments were used in detrending subsequent axes with respect to the first axis.

As in the classification of the vegetation data, species with frequencies less than 5% were removed from the data matrix in the ordination of all the stands with reciprocal averaging and detrended correspondence analysis. In the ordination of the

minor groups of stands that were identified by classification and ordination of all the stands, however, the species that occurred in more than one stand and with frequency greater than 5% were again re-entered into the data matrix.

The program subjected the species with frequencies greater than 5% to downweighting. It downweighted infrequent species by reducing the abundance of species rare than  $m'$  in their frequency, where  $m' = m/5$ ,  $m$  being the frequency of the commonest species. Thus if  $f_j$  was the frequency of species  $j$  and  $a_{ij}$  was the abundance of species  $j$  in stand  $i$ ,  $a_{ij}$  is replaced by  $(a_{ij}) f_j/m'$  for  $f_j$  is smaller than  $m'$ ; and  $f_j$  is defined as  $f_j = \sum (a_{ij})^2 / \sum a_{ij}^2$  which reduces itself to the true frequency of the species when presence and absence data are used.

A detrended correspond analysis - weighted averages hybrid ordination, a technique that combine both detrended correspondence analysis and weighted average ordination in order to graph environmental data with the vegetation data and aid in the interpretation of the ordination results (Gauch, 1977; Gauch and Stone, 1979; and Gauch, 1982) was also tried. In this technique the average values of the

environmental factors for each stand were first standardized to a range of 0-100 and the ordination scores of the stands were used as weights for obtaining weighted averages. The ordination scores of both the weight average ordination and detrended correspondence analysis were then standardized to a range of 0-100.

CHAPTER 4

4. RESULTS AND DISCUSSION

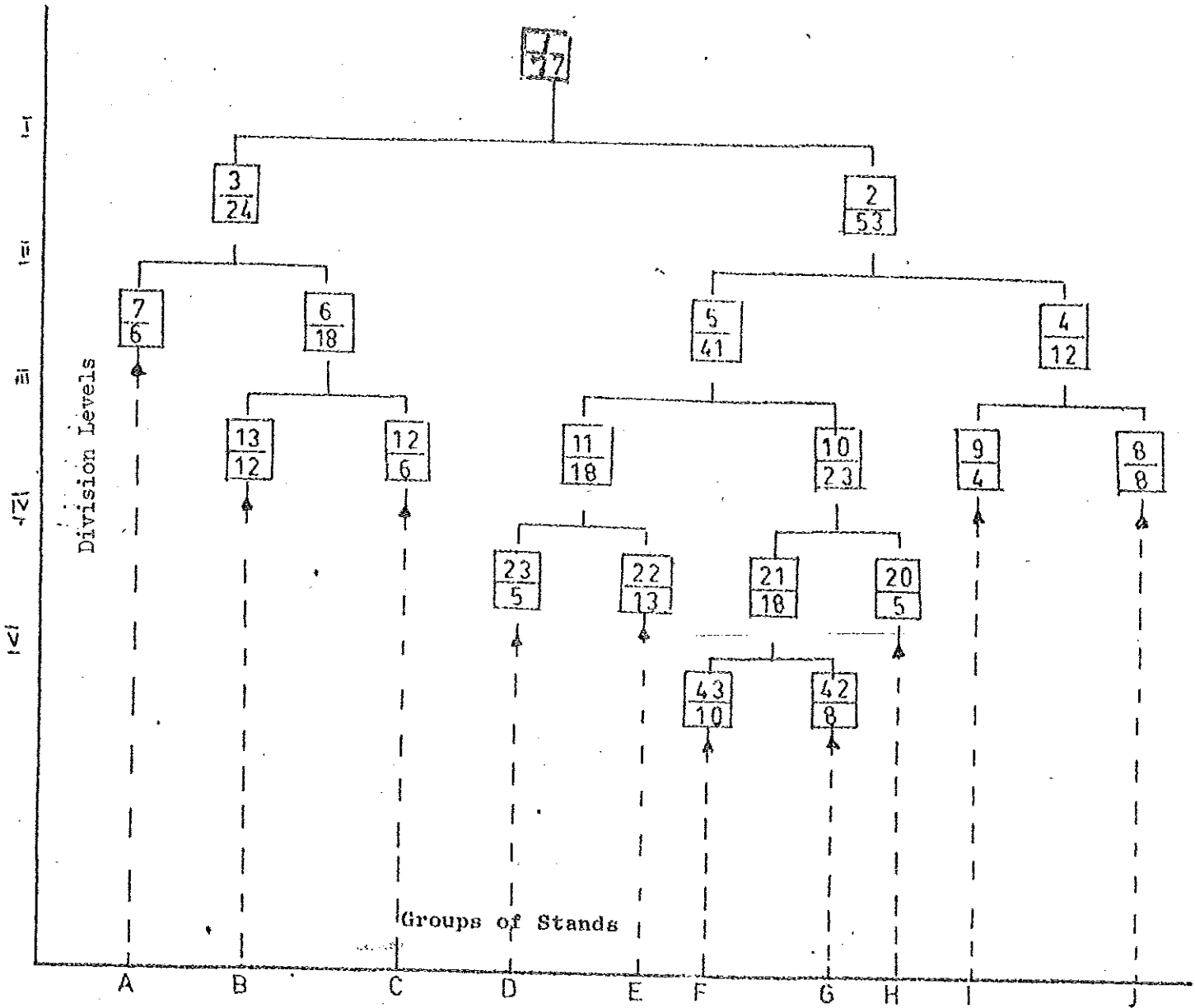
4.1 Classification Studies

4.1.1 Groups Identified by Classification

Both two-way indicator species analysis and association analysis first divided all the stands (group 1 of the dendrogram in figure 2) into groups consisting of the same stands, group 2 with stands 1-53 and group 3 with stands 54-77. The species with frequency less than 5% that were originally removed from the analysis were re-entered for analysis by two-way indicator species analysis and association analysis. This was done because these species had frequencies above 5% after division one and thus their re-entry in the analysis would restore the ecological information they could have carried. Further division by association analysis, however, produced highly fragmented groups and therefore, the division obtained through two-way indicator species analysis were taken as the basis for further studies the results of association analysis being disregarded.

The dendrogram representing the classification of stands by the two-way indicator species analysis is given in Fig. 2. The y-axis represents the division levels and on the X-axis are arranged various groups of stands.

Fig.2 A dendrogram of stand groups of vegetation found on the Eastern Escarpment of Eritrea.



N.B. The numbers in the box represent the group number (numerator) and the number of stands in the group (denominator).

The final homogenous groups that resulted from the analysis are groups No. 7, 8, 9, 12, 13, 20, 22, 23, 42 and 43 and their co-responding letter names given to them for ease in discussion are shown in the dendrogram, figure 2. The stand groups that were formed at every division level with their indicator species are given in Table 4.

#### 4.1.2 Comparison of Stand Groups

The various environmental factors measured were averaged for each of the final 10 homogenous stand groups identified by the two-way indicator species analysis. The average values of the environmental factors measured for each of the final 10 homogenous stand groups is given in Table 5. Each pair of the groups were then compared using the t-test for every environmental factor measured excluding aspect. A probability of 0.05 or lower was considered as significant, and all the environmental factors, except altitude, slope and percentage of rock cover on the surface, were averaged for surface and for all depth of the soils. The results of the comparison are found in Appendix C1-C17. Table 6 gives a summary of the significant contrasts

Table 4 Stand groups formed by the two-way indicator species analysis

Group No.	Stands in the group	Indicator species
2	1-53	
4	1-12	<u>Tribulus terrestris</u>
8 (=I)	1-8	<u>Zygochylum similes</u> , <u>Boerhavia repens</u>
9 (I)	9,12	<u>Digeria alternifolia</u>
5	13-35	<u>Ocimum suave</u> , <u>Spermacoce chaetocephal</u> <u>Crotalaria ononoides</u> , <u>Dodonaea viscosa</u>
10	13-33,39,48	<u>Digeria ternata</u>
20 (=H)	13-17	<u>Justicia heterocarpa</u>
21	18,21-24,39,48	-
42. (=G)	18,21-25,39,48	-
43 (=F)	19,20,26-33	<u>Tephrosia uniflora</u> , <u>combretum molle</u>
11	34,38,40-47	<u>Commelina albascens</u> , <u>Cyphostemma molle</u>
22 (=E)	34,38,40-47	<u>Dodonaea viscosa</u>
23. (=D)	40-53	<u>Crotalaria chrysochloa</u>
3	54-77	<u>Heteropogon contortus</u> , <u>Psidia punctulata</u>
6	60-77	<u>Asparagus falcatus</u> , <u>Monechma debele</u> , <u>Bothriospermum radicans</u> , <u>Oountia ficus-indica</u>
12 (=c)	63-68	<u>Pelargonium alchemilloides</u> .
13 (=B)	60-62,69-77	<u>Harpachne shimperi</u>
7 (=A)	54-49	<u>Enneapogon shimperanum</u> , <u>Justicia striata</u>

Table 5: Average values of environmental factors for the final homogenous stand groups

Groups	No. stand	Alt. Meter	Slope deg.	Sur-face rock %	Sand %		Silt %		Clay %		Color		Organic Matter %			
					Sur-face	Ave- rage	Sur-face	Ave- rage	Sur-face	Ave- rage	Hue Surface	Value Chroma		sur- face	Ave- rage	
												Average	Average			
A	6	1572	14.2	68	78.25	79.58	7.32	13.93	14.21	6.32	9.17	$\frac{4.83}{6.00}$	8.96	$\frac{5.27}{4.57}$	1.97	1.30
B	12	1913	23.2	49	83.93	84.74	12.69	11.99	3.40	3.27	9.76	$\frac{6.67}{4.17}$	9.91	$\frac{5.20}{4.57}$	2.94	1.42
C	6	1802	43.7	62	77.64	77.98	17.14	16.63	5.22	5.39	9.17	$\frac{3.67}{2.33}$	9.45	$\frac{4.13}{3.31}$	5.63	3.41
D	5	1396	27.2	54	82.67	87.80	13.01	9.09	4.72	3.10	10.00	$\frac{3.80}{4.80}$	10.00	$\frac{5.40}{4.82}$	4.08	1.57
E	13	1125	20.4	42	78.68	80.73	14.28	14.09	7.04	5.17	8.08	$\frac{4.46}{3.62}$	9.14	$\frac{5.42}{4.81}$	2.04	1.01
F	10	754	24.9	73	78.28	79.58	14.92	15.15	6.84	5.37	9.75	$\frac{4.80}{3.30}$	8.76	$\frac{5.81}{5.13}$	1.50	0.69
G	8	824	23.8	79	75.87	77.46	19.11	18.88	5.02	4.17	10.00	$\frac{4.86}{3.43}$	10.00	$\frac{5.55}{4.07}$	2.17	0.72
H	5	412	9.6	62	77.62	77.46	18.02	17.87	4.34	5.20	10.00	$\frac{5.00}{3.80}$	10.00	$\frac{5.54}{4.45}$	1.07	0.72
I	4	368	6.3	24	63.56	61.00	28.00	25.31	8.44	13.66	10.00	$\frac{5.00}{4.25}$	10.00	$\frac{5.33}{4.48}$	2.13	0.71
J	8	198	2.4	39	69.59	72.99	23.98	19.06	6.81	7.00	10.63	$\frac{5.35}{3.38}$	10.00	$\frac{5.39}{3.52}$	0.76	0.37

Tabel 5 continued

Groups	PH		Cond. m mhos/cm		K meq/100g soil		Ca meq/100g soil		Mg meq/100g soil		Na meq/100g soil		Mn meq/100g soil	
	Sur- face	Ave- rage	Sur- face	Ave- rage	Sur- face	Ave- rage	Sur- face	Ave- rage	Sur- face	Ave- rage	Sur- face	Ave- rage	Sur- face	Ave- rage
A	7.32	7.18	0.130	0.440	0.16	0.12	14.67	17.32	3.31	3.85	0.28	0.54	0.037	0.030
B	7.12	6.99	0.650	0.092	0.12	0.10	17.43	13.99	4.91	5.24	0.24	0.28	0.036	0.024
C	6.52	6.63	0.320	0.140	0.20	0.14	18.92	18.07	5.60	5.60	0.21	0.28	0.10	0.062
D	7.54	7.80	0.085	0.082	0.02	0.07	17.70	15.97	3.60	2.70	0.15	0.20	0.036	0.070
E	6.96	7.19	0.045	0.030	0.14	0.15	12.19	11.46	4.57	4.40	0.15	0.18	0.030	0.020
F	6.88	7.03	0.060	0.042	0.23	0.14	10.78	9.56	2.51	2.61	0.16	0.18	0.041	0.018
G	7.56	7.42	0.059	0.052	0.19	0.12	19.38	16.88	2.74	2.74	0.19	0.23	0.032	0.018
H	7.44	7.63	0.100	0.058	0.32	0.23	16.55	23.92	2.34	2.27	0.19	0.26	0.040	0.030
I	7.75	7.94	0.280	0.250	0.92	1.15	35.62	43.14	3.24	5.91	0.39	4.31	0.049	0.015
J	8.06	7.83	0.740	1.560	1.22	1.25	32.06	38.20	2.46	2.74	1.25	2.52	0.020	0.012

Table 6 Summary of the comparison of stand groups using the t-test based on the average values of the environmental factors (The numbers in the table represent the total significant contrast each group showed)

Group No.	Alt	Slope	Surface rock Cover %	Sand		Silt		Clay		Hue		Value		Chroma	
				Sur	Ave	Sur	Ave	Sur	Ave	Sur	Ave	Sur	Ave	Sur	Ave
A	9	1	1	1	1	2	1	2	2	3	1	1	1	6	-
B	8	4	2	8	9	5	6	6	4	1	2	5	2	2	2
C	8	8	-	3	2	2	2	3	-	-	-	8	8	7	4
D	9	5	1	3	7	3	9	2	4	1	1	5	1	2	1
E	9	4	2	3	4	3	4	5	3	7	2	3	1	3	2
F	8	4	3	3	4	2	2	3	4	2	5	3	2	1	2
G	6	4	6	4	2	3	3	1	-	2	2	3	1	1	-
H	8	8	1	3	2	1	2	2	-	1	-	2	1	2	-
I	8	5	2	7	4	5	4	1	3	2	2	1	-	0	-
J	9	8	2	7	4	6	3	1	-	3	1	3	1	2	1
Total Significant contrasts	82	52	20	42	40	32	36	26	20	22	16	34	18	26	18

Table 6 continued

Group No.	Cond		p <sup>H</sup>		O.M.		K		Ca		Mg		Na		Mn	
	Sur	Ave	Sur	Ave	Sur	Ave	Sur	Ave	Sur	Ave	Sur	Ave	Sur	Ave	Sur	Ave
A	3	3	1	3	4	6	3	3	2	1	3	5	4	2	2	1
B	5	3	1	3	6	6	5	3	4	3	5	5	8	1	2	5
C	3	2	3	3	7	9	4	2	4	4	6	6	3	3	4	3
D	1	4	3	5	4	4	4	4	2	1	2	3	3	1	-	2
E	5	7	5	3	6	2	5	4	4	5	2	3	4	4	2	3
F	3	4	5	4	5	5	4	4	5	5	5	4	6	6	-	4
G	4	4	3	0	2	5	2	2	1	3	2	2	3	2	1	2
H	1	3	4	1	5	3	6	5	2	2	3	3	3	2	2	1
I	3	5	3	5	2	4	6	8	7	3	2	2	5	2	2	1
J	2	7	6	5	5	8	8	7	7	7	4	3	5	7	3	4
	30	42	34	32	46	52	46	42	38	34	34	36	44	30	18	28

each group showed in the comparison using the t-test for every environmental factor measured.

#### 4.1.3 Correlations among the Environmental Factors

The classification technique identified the discontinuities in the vegetation and delimited the stands into groups having similar characteristics. This was supported by the significant contrasts found between stand groups as shown by the t-test. There were, however, similar environmental conditions occupied by the different groups of stands. To see variation of vegetation and environment and reveal the similarities between the different groups, Spearman's rank correlations of the stand groups based on their average environmental factors were computed. Table 7 gives the ranking of each stand group with respect to the averages of all the environmental factors of the stands in that group. The correlation coefficients determined among the environmental factors with the level of significance is given in Table 8.

Table 7 Ranks of the final homogeneous stand groups based on the average Values of the environmental factors

Group	Alt- itude	slope	Surface Rock cover %	Sand		Si-t		Clay		Hue		Value		Chroma	
				Sur- face	Ave- rage	Sur- face	Ave- rage	Sur- face	Ave- rage	Sur- face	Ave- rage	Sur- face	Ave- rage	Sur- face	Ave- rage
A	3	7	3	5	4	10	8	1	3	8	9	6	8	1	2
B	1	5	7	1	2	9	9	10	10	7	6	1	9	4	5
C	2	1	4	6	6	5	5	6	4	8	7	10	10	10	10
D	4	2	6	2	1	8	10	8	9	2	3	9	5	2	3
E	5	6	8	3	3	7	7	3	7	10	8	8	4	6	4
F	7	3	2	4	4	6	6	4	5	6	10	7	1	9	1
G	6	4	1	8	7	3	3	7	8	2	3	5	2	7	8
H	8	8	4	7	7	4	4	9	6	2	2	3	3	5	7
I	9	9	10	10	10	1	1	2	1	2	3	3	7	3	6
J	10	10	9	9	9	2	2	5	2	1	1	2	6	8	9

Table 7 Continued

Group	COND.		PH		O.M.		K		Ca		Ma		Na		Ma	
	Sur-face	Ave-rage	Sur-face	Ave-rage	Sur-face	Ave-rage	Sur-face	Ave-rage	Sur-face	Ave-rage	Sur-face	Ave-rage	Sur-face	Ave-rage	Sur-face	Ave-rage
A	5	3	5	7	7	4	7	7	8	5	4	5	3	3	5	3
B	8	1	7	9	3	3	9	9	6	8	2	3	4	4	6	6
C	2	1	10	10	1	1	5	5	4	4	1	2	5	4	1	2
D	10	10	4	3	2	2	9	10	5	7	6	7	8	8	6	1
E	8	9	8	6	6	3	8	4	9	3	4	8	8	9	9	7
F	7	8	9	8	8	9	4	5	10	10	8	8	8	9	3	5
G	4	5	3	5	4	6	6	7	3	6	7	9	6	7	8	8
H	5	6	6	4	9	6	3	3	7	3	10	10	6	6	4	3
I	1	1	2	2	5	8	2	2	1	1	5	1	2	1	2	9
J	2	3	1	1	10	10	1	1	2	2	9	6	1	2	10	10

Table 8: Correlation between the Environmental Factors

	Altitude	Slope	%Rock Cover	%Sand Sur.	%Sand Ave.	%Silt Sur.	%Silt Ave.	%Clay Sur.	%Clay Ave.	Hue Sur.	Hue Ave.	Value Sur.	Value Ave.	Chroma Sur.	Chroma Ave.
Altitude R	-														
P															
Slope R	0.739	-													
P	0.01														
%Rock R	-0.180	0.367	-												
P	-	0.50													
%Sand R	0.734	0.552	-0.103	-											
P	0.05	0.20	-												
%Sand R	0.764	0.582	0.012	0.970	-										
P	0.02	0.10	-	0.001											
%Silt R	-0.770	-0.592	0.067	-0.964	-0.921	-									
P	0.02	0.10	-	0.001	0.001										
%Silt R	-0.952	-0.527	0.030	-0.952	-0.933	0.988	-								
P	0.001	0.20	-	0.001	0.001	0.001									
%Clay R	-0.466	-0.442	-0.152	-0.466	-0.424	0.479	0.455	-							
P	0.20	0.50	-	0.20	0.5	0.20	0.20								
%Clay R	-0.503	-0.564	-0.090	-0.721	-0.715	0.648	0.661	0.722	-						
P	0.20	0.1	-	0.05	0.05	0.05	0.05	0.05							
Hue R	-0.800	-0.750	-0.230	-0.727	-0.624	0.448	0.352	-0.327	-0.096	-					
P	0.01	0.02	-	0.05	0.10	0.50	0.50	0.50	-						
Hue R	-0.618	-0.509	-0.351	-0.618	-0.515	0.497	0.540	-0.218	-0.060	0.891	-				
P	0.10	0.20	0.5	0.10	0.2	0.2	0.2	-	-	0.002					
Value R	-0.412	-0.776	-0.448	-0.352	-0.406	0.267	0.364	-0.33	0.170	0.406	0.430	-			
P	0.5	0.02	0.5	0.5	0.5	0.5	0.5	-	-	0.5	0.5				
Value R	-0.527	0.006	0.564	-0.078	-0.048	0.212	0.102	-0.018	-0.260	0.122	0.012	-0.072	-		
P	0.20	-	0.10	-	-	-	-	-	0.5	-	-	-			
Chroma R	0.176	0.284	0.236	0.212	0.340	-0.370	-0.575	-0.054	-0.139	0.024	0.048	0.182	-0.212		
P	-	0.5	-	-	0.5	0.5	0.10	-	-	-	-	-	-		
Chroma R	0.200	-0.284	0.163	0.630	0.521	-0.739	-0.545	0.158	-0.09	-0.527	-0.690	-0.230	0.285	0.479	-
P	-	0.5	-	0.10	0.20	0.05	0.20	-	-	0.20	0.05	-	0.5	0.20	

Table 8 continued

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		pH	pH	Cond.	Cond.	O.M.	O.M.	K	K	Ca	Ca	Mg	Mg	Na	Na	Mu	Mu
		Sur.	Ave.	Sur.	Ave.	Sur.	Ave.	Sur.	Ave.	Sur.	Ave.	Sur.	Ave.	Sur.	Ave.	Sur.	Ave.
Altitude	R	-0.636	-0.770	-0.170	-0.406	0.709	0.885	-0.788	-0.733	-0.466	-0.479	0.479	0.321	-0.570	-0.200	0.182	0.564
	P	0.10	0.05	-	0.5	0.05	0.005	0.02	0.05	0.20	0.20	0.20	0.50	0.10	-	-	0.10
Slope	R	-0.636	-0.624	-0.345	-0.661	0.721	0.642	-0.521	-0.624	-0.255	-0.612	0.230	-0.042	-0.570	-0.600	0.327	0.430
	D	0.10	0.10	0.50	0.05	0.05	0.10	0.20	0.10	-	0.10	-	-	0.20	0.10	0.50	0.50
%Rock C.	R	-0.212	-0.236	0.297	-0.358	-0.139	-0.042	0.109	-0.127	-0.267	-0.236	0.733	-0.673	-0.352	-0.333	0.133	0.370
Surface	P	-	-	0.50	0.50	-	-	-	-	0.50	-	0.05	0.05	0.5	0.5	-	0.5
% Sand	R	-0.600	-0.564	-0.527	-0.636	0.370	0.582	-0.891	-0.697	0.661	-0.527	0.164	-0.036	-0.485	-0.503	-0.073	0.382
Surface	D	0.10	0.10	0.20	0.10	0.50	0.10	0.002	0.05	0.05	0.20	-	-	0.20	0.20	-	0.5
% Sand	R	-0.473	-0.448	-0.485	-0.594	0.436	0.673	-0.794	-0.727	-0.570	-0.746	0.170	-0.012	-0.479	-0.497	-0.103	0.388
Surface	P	0.20	0.50	0.20	0.10	0.50	0.05	0.01	0.05	0.10	0.02	-	-	0.20	0.20	-	0.5
% Silt	R	0.539	0.564	0.406	0.503	-0.370	-0.630	0.909	0.806	0.667	0.709	-0.103	-0.042	0.449	0.479	0.073	-0.503
Average	P	0.20	0.10	0.50	0.20	0.50	0.10	0.001	0.01	0.05	0.05	-	-	0.50	0.20	-	0.20
% Silt	R	0.503	0.491	0.394	0.515	-0.382	-0.642	0.909	0.818	0.685	0.697	0.079	-0.212	0.509	0.527	0.073	-0.491
Average	P	0.20	0.20	0.50	0.20	0.50	0.10	0.001	0.01	0.05	0.05	-	-	0.20	0.20	-	0.20
% Clay	R	0.133	0.358	0.212	0.152	-0.321	0.473	0.436	0.636	-0.146	0.261	0.503	0.679	0.327	0.273	-0.061	-0.442
Surface	P	-	0.50	-	-	0.50	0.20	0.50	0.10	-	0.50	0.20	0.05	0.5	0.5	-	0.50
% Clay	R	0.212	0.248	0.697	0.661	-0.455	-0.497	0.739	0.770	0.309	0.661	0.042	0.370	0.739	0.648	0.303	-0.139
Average	P	-	0.5	0.05	0.05	0.20	0.20	0.05	0.02	0.50	0.05	-	0.50	0.05	0.05	0.50	-
Hue	R	0.812	0.715	0.218	0.448	-0.327	-0.527	0.479	0.097	0.618	0.497	-0.509	-0.546	0.212	0.388	-0.285	-0.776
Surface	P	0.01	0.05	-	0.50	0.50	0.20	0.20	-	0.10	0.20	0.20	0.20	-	0.5	0.5	0.02
Hue	R	0.842	0.739	0.315	0.533	-0.170	-0.285	0.448	0.242	0.727	0.630	-0.285	-0.012	0.212	0.288	-0.345	-0.679
Average	P	0.01	0.05	0.5	0.20	-	-	0.50	-	0.05	0.10	0.5	-	-	0.20	0.50	0.05
Value	R	0.545	0.327	0.158	0.533	-0.485	-0.515	0.339	0.291	0.302	0.376	-0.255	-0.061	0.691	0.103	-0.261	-0.485
Surface	P	0.20	0.50	-	0.20	0.20	0.20	0.50	0.50	0.50	0.50	0.50	-	0.05	0.05	0.5	0.20
Value	R	0.127	0.273	-0.600	-0.455	-0.455	-0.509	0.291	0.139	-0.297	-0.358	-0.689	-0.794	-0.509	-0.403	-0.255	-0.236
Average	P	-	0.5	0.10	0.20	0.20	0.20	0.50	-	0.50	0.50	0.05	0.01	0.20	0.20	0.50	-
Chroma	R	0.345	0.345	0.180	0.188	0.079	0.255	-0.291	-0.358	-0.024	0.285	0.188	0.103	0.218	0.358	-0.024	-0.055
Surface	P	0.50	0.50	-	-	-	0.50	0.50	0.50	-	0.50	-	-	-	0.50	-	-
Chroma	R	-0.213	-0.127	-0.479	-0.467	-0.127	0.000	-0.352	-0.382	-0.509	-0.630	-0.218	-0.133	-0.327	-0.297	0.061	0.164
Average	P	0.50	-	0.20	0.20	-	-	0.50	0.50	0.20	0.10	-	-	0.50	0.50	-	-

Table 8 Continued

		pH	pH	Cond.	Cond.	O.M.	O.M.	K	K	Ca	Ca	Mg	Mg	Na	Na	Mu	Mu
		Sur.	Ave.	Sur.	Ave.	Sur.	Ave.	Sur.	Ave.	Sur.	Ave.	Sur.	Ave.	Sur.	Ave.	Sur.	Ave.
pH	R	-															
Surface	P																
pH	R	0.891	-														
Average	P	0.002															
Cond.	R	0.309	0.248	-													
Surface	P	0.5	0.5														
Cond.	R	0.564	0.467	0.891	-												
Average	P	0.10	0.20	0.002													
O.M.	R	-0.297	-0.358	-0.115	-0.321	-											
Surface	P	0.50	0.50	-	0.50												
O.M.	R	-0.461	-0.497	-0.061	0.242	0.800	-										
Average	P	0.20	0.20	-	-	0.01											
K	R	0.521	0.545	0.521	0.630	-0.558	-0.697	-									
Surface	P	0.20	0.20	0.20	0.10	0.20	0.05										
K	R	0.285	0.430	0.442	0.515	-0.600	-0.630	0.860	-								
Average	P	0.50	0.50	0.50	0.20	0.10	0.10	0.005									
Ca	R	0.697	0.539	0.564	0.600	0.236	-0.109	0.461	0.273	-							
Surface	P	0.05	0.20	0.10	0.10	-	-	0.20	0.50								
Ca	R	0.612	-0.200	0.818	0.915	-0.036	-0.206	0.679	0.588	0.746	-						
Average	P	0.10	-	0.01	0.001	-	-	0.05	0.10	0.02							
Mg	R	-0.236	0.164	0.067	-0.000	0.746	0.558	0.030	-176	0.879	0.018	-					
Surface	P	-	-	-	-	0.02	0.20	-	-	0.002	-						
Mg	R	-0.176	0.267	0.345	0.200	0.442	0.279	0.455	0.115	0.883	0.200	0.900	-				
Average	P	-	0.50	0.50	-	0.50	0.50	0.20	-	0.005	-	0.001					
Na	R	0.473	0.430	0.788	0.873	0.206	-0.206	0.564	0.485	0.582	0.752	0.146	0.461	-			
Surface	P	0.20	0.50	0.02	0.005	-	-	0.10	0.20	0.10	0.02	-	0.2				
Na	R	0.624	0.545	0.721	0.891	-0.139	0.170	0.545	0.430	0.661	0.800	0.175	0.485	0.958	-		
Average	P	0.10	0.20	0.05	0.002	-	-	0.20	0.50	0.05	0.01	-	0.20	0.001			
Mu	R	-0.400	-0.279	0.315	0.170	0.315	0.261	0.152	0.048	0.139	0.194	0.388	0.370	-0.873	0.133	-	
Surface	P	0.50	0.50	0.50	-	0.50	0.50	-	-	-	-	0.50	0.50	0.005	-		
Mu	R	-0.806	-0.745	-0.018	-0.176	0.139	0.570	-0.327	-0.272	-0.636	-0.158	0.018	-0.067	0.206	-0.248	0.558	
Average	P	0.01	0.02	-	-	-	0.10	0.50	0.50	0.10	-	-	-	-	-		

#### 4.1.4 Interactions in the Ecosystem

Two-way indicator species analysis divided the stands into groups that contrasted significantly in altitude. Group 3, whose indicator species were Psidia punctulata and Heteropogon contorus had stands that were situated at higher altitudes, ranging from 1550 meters to 2075 meters above sea level, than stands of group 2 whose altitudes ranged from 190 meters to 1400 meters above sea level. Altitude is an important environmental factor affecting atmospheric pressure, moisture, temperature which has a strong influence on the growth and development of plants and distribution of vegetation (Hebderg, 1954, 1968; Oasting, 1956).

On the Eastern Escarpment of Eritrea rainfall seems to be the most important climatic factor associated with altitude. Stands situated at higher altitudes had received moisture from both the summer rains and the winter rains. However, the winds had reached them after having lost much of their moisture and thus had released only small amounts of rain. Groups, A, B and C, which were the results of the division of group 3, fell under this category. On

the other hand stands at medium elevation had received higher amounts of moisture because the winter rains had released much higher amounts of rain. Groups D, E, F and G which were the results of the division of group 2 stands could be categorized under this range of rainfall. Group H, I, and J which were also the results of the division of group 2, had the lowest altitudes and had been under the influence of the winter rains and had only got the least amount of rain.

In the study area, slope has been found to be strongly correlated to altitude ( $r = 0.737$  significant at  $P > 0.05$ ). Slope, by affecting the intensity of light, moisture differences, runoff, the amounts of soil water and erosion, also affects the distribution of vegetation (Oasting, 1956). Thus groups A, B and C, being on steep slopes coupled with the small amounts of rain, they get arid. For this reason drought tolerant succulent species, e.g., Opuntia ficus-indica, Aloe sp., Cissus sp. and Euphorbia tirucalli were found to be among the species common to these groups.

As the loss of nutrients through leaching is determined by climatic factors and the nature of the bed rock, regions with high percolation have a high

potential for leaching (Buckman and Brandy, 1974).

Thus loss of nutrients was bound to be small in groups A, B, C, J, I and H which were found under arid conditions. The ranking of the groups of stands according to decreasing conductivities supported this expectation. This ranking being C,I,B,J,G,H,A,F,E, and D for average of surface conductivities and I, J, C, G,A,H, F,E,B and D for average conductivities over all the depths.

Spearman's rank correlation revealed that the percentage of organic matter of the soils was positively correlated with altitude and slope. The ranking of the groups of stands according to the decreasing amounts of organic matter was C,D,B,G,I,E,A,F,H and J for surface values and C,D,B,A,E,H,G,I,F and J for average values over all the depth of the soils. This may be in contradiction with the expectation that soils of stand groups with steep slopes should have less organic matter owing to the loss of soils through erosion (Thompson and Troeh, 1978). However, groups B and C which were located on the steepest soils were at the highest altitudes and the area had been terraced for the last 50 years. Moreover, Opuntia ficus-indica, which was introduced to the study are in

the last century to reduce erosion of the areas around the railway from Asmera to Mitswa, has proliferated successfully throughout the escarpment above the altitudes of 1800 meters above sea level. This species is observed to hold the soils well, and thus would have contribute some percentage to the organic matter content of the soils. The lower temperature associated with the higher altitudes and the drier environment of the stand groups would also reduce decomposition resulting in the accumulation of organic matter in soil.

Groups J and H, on the other hand, have the least amounts of organic matter. This can be attributed to the low biomass production in the arid conditions in which the groups were found.

Altitude, slope organic matter and conductivities of the soils also should significant correlations with some of the exchangeable cations of soil measured.

The cations sodium, potassium and calcium had their highest concentrations in groups I and J. This was to be expected because these groups of stands occurred in the area which had received least amount of rain and highest temperatures resulting in little loss by leaching. Moreover, the slow rate of nutrient

cycling resulting from poor biomass production, slow rates of nutrients uptake and release by plants and slow rates of litter decomposition in arid lands could have contributed substantially to the high accumulation of the cations (West, 1981).

In the other groups of stands the concentration of the cations fluctuated depending upon the amounts of organic matter the soils contained the humidity of the area and soil texture.

Soil texture is another important environmental factor in that determines the concentration of nutrients by affecting cation exchange capacity, water holding capacity and aeration of the soils. Differences in texture amongst the groups were not very significant. Nevertheless some significant correlations were obtained between cation concentrations and clay and silt percentages of the soils. For instance, the spearman's rank correlation coefficient ( $r$ ) between potassium content of the soils averaged over all the depth and percentage of silt of the soils is 0.909 (significant at  $P < 0.001$ ) and between calcium content of the soils averaged over all the depth and silt content of soils averaged over all the depth is 0.697 (significant at  $P < 0.05$ ).

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Another important chemical factor closely related to concentration of cations, organic matter in soil and texture of the soils was the soil pH. pH has little or no direct effect on plants but on the release and availability of nutrients. High pH's are associated with high amounts of the acidic cations  $Al^{+3}$  and  $H^{+}$  and low basic cations (Buckman and Brandy, 1974). Thus the soils that are highly leached have lower pH because the basic cations have lower proportions than the acidic cations. Of course, the nature of the parent material has also a strong influence on the concentration of the different cations and thus on the pH. Significant <sup>by</sup> positive correlations between the concentrations of cations Ca, K and Na and negative correlations with the cation manganese were obtained as expected.

Related to the soil organic matter, climate, soil drainage, and soil mineralogy is the soil color. Lower layers of soil may be very nearly the color of their constituent minerals with the influence of humus, climate and drainage showing more towards the surface. (Buckman and Brady, 1974; Pitty, 1978; Thompson and Troech, 1978). In arid regions the soil color is strongly influenced by the natural color of parent material because humus and iron are low (Thompson and Troech, 1978). As expected the color of

groups H,I, and J found under the arid conditions of lower altitudes, had higher YR values representing mainly the color of the soils of parent materials, while groups A,B,C,E and F had lower values of YR probably because of higher organic matter contents and the effects of enhanced weathering owing to higher moisture.

Comparing the groups of stands that resulted from the division of group 3, group A equivalent to group 7, had a lower average altitude than group 6. The indicator species for group A were Justicia striata and Enneapogo shimperanun and for group 6 they were Asparagus falcatus, Monechma debele, Bothriochloa radicans and Opuntia ficus-indica. Group A soil have higher clay contents, than groups B and C (the result of the division of group 6) the contrast being significant at  $P < 0.001$  for A and B, and at  $P < 0.05$  for A and C for the surface average and at  $P < 0.005$  for A and B for the average values overall the depths. Under the arid conditions in which the groups were found, the more clayey soils of A had retained higher amounts of sodium with group A having significantly higher amounts of sodium than B at  $P < 0.001$ , and at  $P < 0.05$  than C for the average of the surface values, Soils with a higher than normal

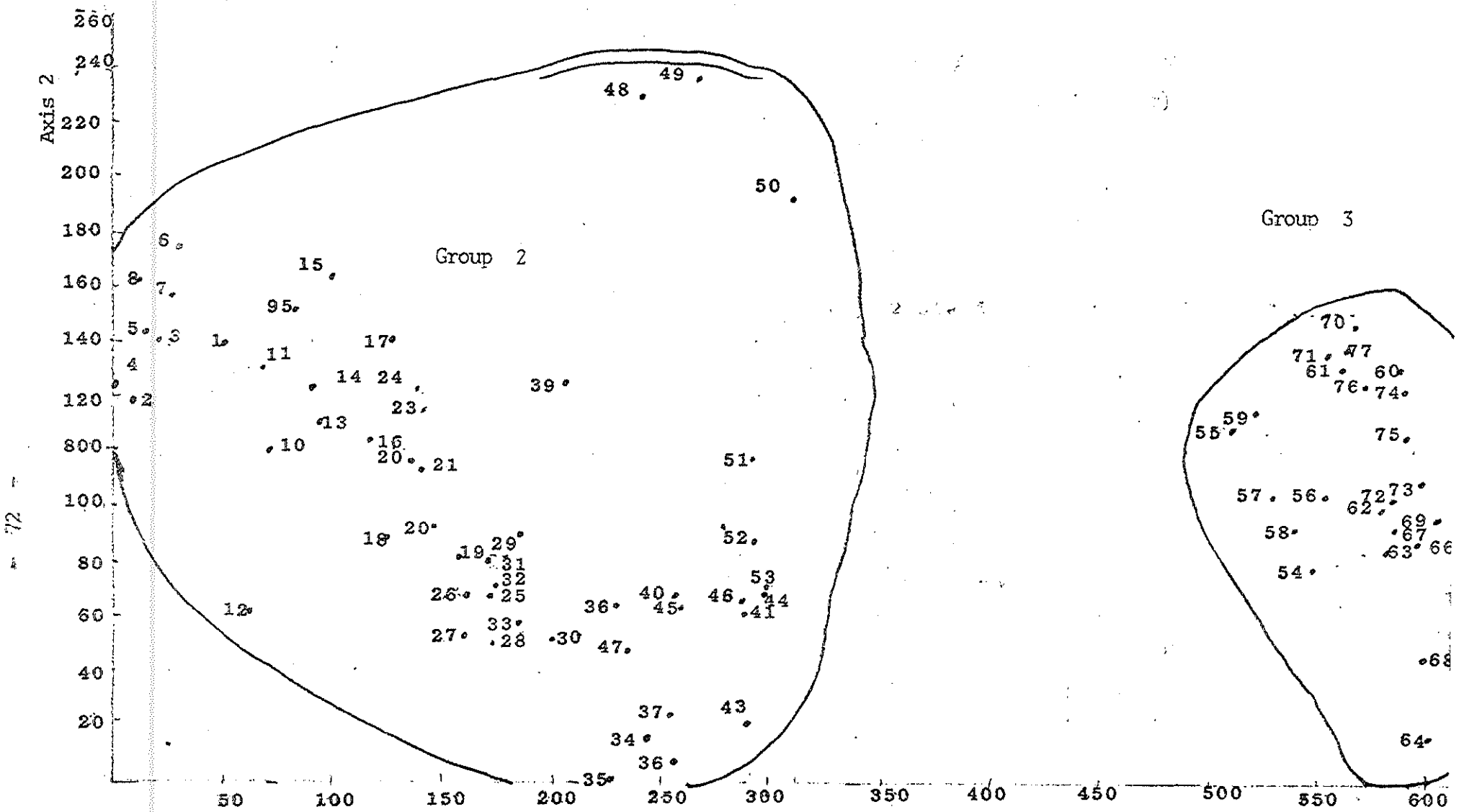


Fig 3 Detrended correspondence analysis ordination diagram of the stands  
 (Each number in the diagram correspondence to a stand number)

content of sodium tend to disperse creating unfavourable conditions for the entry and movement of water which in turn has adverse effects on the growth and development of plants (United States Salinity Laboratory Staff, 1954). In agreement with this, the percentage of organic matter in the soils of group A was lower than group B and C, the contrast being significant between A and C. ( $P < 0.001$  for surface values and at  $P < 0.01$  for average values over all the depths). The higher amounts of organic matter had significant effects on the concentration of exchangeable cations in the soils as group C had higher amounts of the cations K, Ca, Mg and Mn, than both group A and B. This could be explained by the higher accumulation of these metabolically important cations in the above ground part of the plants and their release to the ground on death and decay of the plant (Cf. Binet, 1981).

Group C and B had significant differences in altitude and slope. The indicator species for group B was Pelargonium alchemilloides and for group C Harpachne shimperi. Many of the stands in group B had altitudes approaching or even exceeding the 2000 meters above sea level. This altitude is indicated by

Abul-Haggag (1961) as the demarcation line above which the winter rains release little or no moisture to the region. Some of the stands (e.g. 70,71,76 and 77 of group B were located in the rain shadow of the winter rains. Thus group B could be said to be under more arid condition than group C. Moreover, agricultural systems were more developed at altitudes above 2000 meters. Permanent villages that perform cultivation similar to those of the plateau were found in areas near group B stands. Thus the group B stands, having lower slopes than group C stands, were more exposed to human interferences than group B stands with very steep slopes. Therefore, the generally more arid conditions prevailing in group B stands and higher human interference in group B than A could have reduced substantially the diversity of plants in B and enhanced erosion. For this reason the percentage of organic matter in group B was significantly lower than in group C ( $P < 0.005$  for surface and  $P < 0.001$  for average over all the depths). Parallel to this there were higher concentrations of exchangeable cations in group C than in B.

At division level II group 2 was divided into group 5 whose indicator species were Ocimum sauve, Spermococe chaetocephala, Crotolaria ononoides and

Dodonaea viscosa, and group 4 whose indicator species is Tribulus terrestris. As indicated in the discussion above the stands of group 4 were situated at lower altitudes getting lower amounts of rain than group 5 stands. Group 4 stands had generally higher concentration of cations, higher conductivities and pH, and higher YR values, lower content of organic matter and lower slopes.

At division level II group A was divided into groups I and J. The indicator species for group I was Digeria alternifolia and for group J they were Zygo-phyllum simplex and Boerhavia refens. The stands of group I situated in the Ailet plain at the base of the escarpment have higher altitude than group J stands which are found in more arid conditions not only because group I stands (except for stand No. 9) could have had higher soil moisture owing to higher amounts of underground water at the base of the escarpment. The soil texture of group I and J also showed some differences. Group I had higher clay and silt proportions than group J although not significantly. Clay having higher water and nutrient retaining capacity, the strongly adsorbed cations in the cation exchange site Ca, Mg, Na, are found in higher amounts in group J than I. Moreover, the soils of the group I stands had

received more organic matter laden eroded soils from the escarpment which had more plant cover, than group J stands which had received eroded soils from the relatively dried hills surrounding the Mai Atal plain. Organic matter having a strong influence upon the structural aggregates, retention of moisture and adsorption of nutrients in the soil (Etherington, 1975) had led to a more proliferated growth of plants and higher diversity of plant species in I than J. This in turn would mean the addition of more organic matter to the ground and faster nutrient cycling.

At division level II group 5 divided into group 10 whose indicator species were Digeria ternata and Acacia tortillis and group 11 whose indicator species was Dodonaea viscosa. Group 10 had a lower average altitude than group 11, and this meant that group 10 stands were under more winter rains influence than group 11 stands. More settlements of highlands farmers and Soho pastoralists, who migrate in the winter season to the escarpment to cultivate some crops, were observed towards the base of the escarpment around which most of the group 10 stands were situated. This agricultural activity would mean, however, that there was more interferences in the natural ecosystem of the region of group 10 resulting in less plant cover and

more erosion. To support this, group 10 had a higher average rock percentage exposure at the surface, and less organic matter in the soil. There were not however, many significant contrasting among the groups that were divided between group 11 and group 10 on the exchangeable cations concentration, except for group H. Group H stands were found at the base of the Sabarguma hills, under more arid conditions and with lower slopes and higher clay and silt content which had been eroded from the hills resulting in the accumulation of cations. The significant contrast of group H is not, however, only with the groups identified for group 11 but also with the groups that made up group 10.

#### 4.2 Ordination Studies

Both reciprocal averaging and detrended correspondence analysis distributed the stands along the first axis according to their altitude stands with high altitude having low ordination scores and stands with low altitude having high ordination scores. The ordination scores of the stands are given in Appendix D1. As indicated in the introduction, moisture is the most important environmental factor that is associated with altitude. Thus, it could be said that the ordination diagrams (Fig. 3,4) for both reciprocal averaging and detrended correspondence analysis show the distribution of stands along a moisture gradient.

As is seen in the ordination diagrams both reciprocal averaging and detrended correspondence analysis formed two disjunct sets of stands which coincided with the group 2 stands and group 3 stands that were formed by both the two-way indicator species analysis and the association analysis.

Group 2 and group 3 stands were thus ordinated separately in order to obtain continuous subsets (Gauch, 1977).

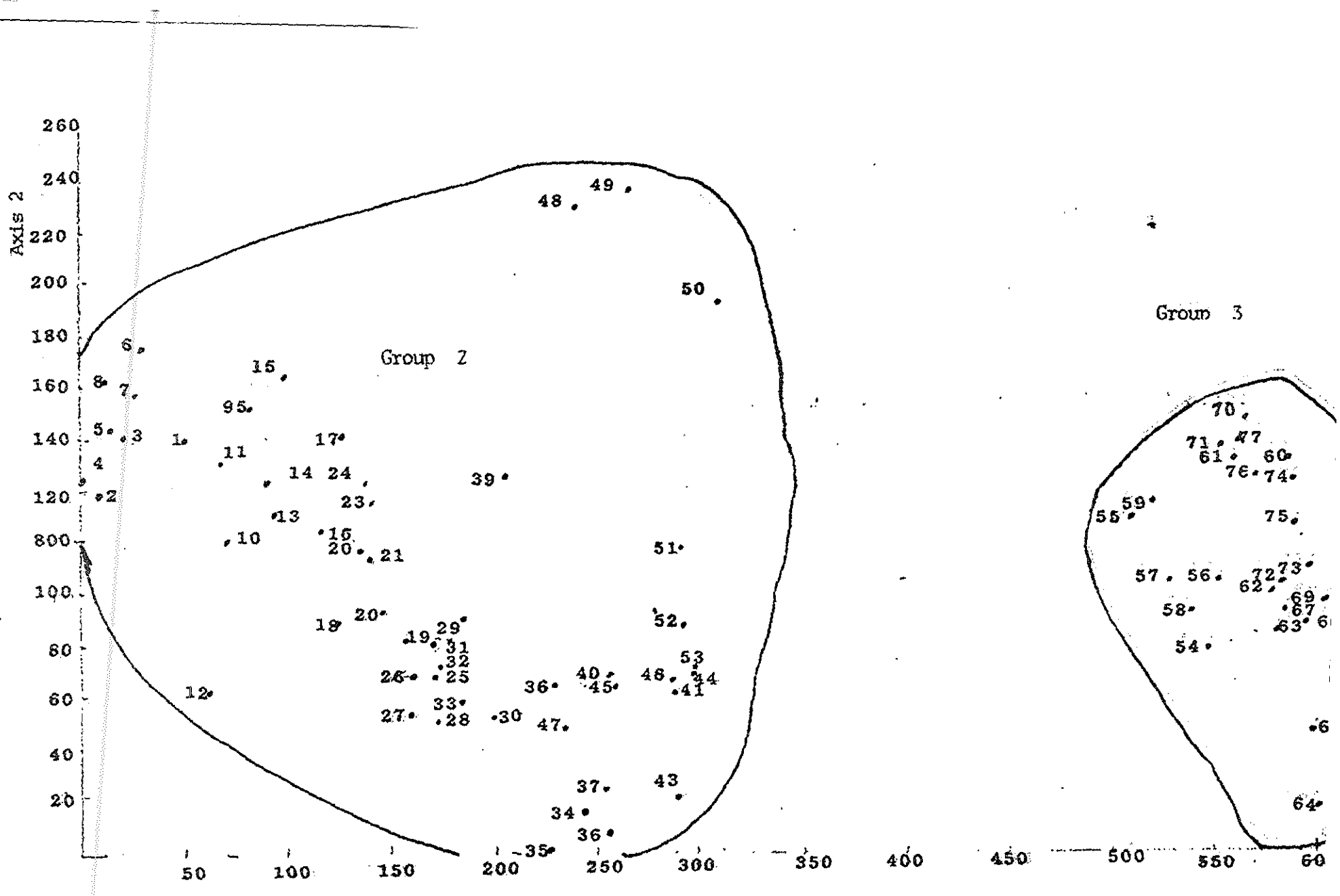


Fig 3 Detrended correspondence analysis ordination diagram of the stands  
 (Each number in the diagram correspondence to a stand number)

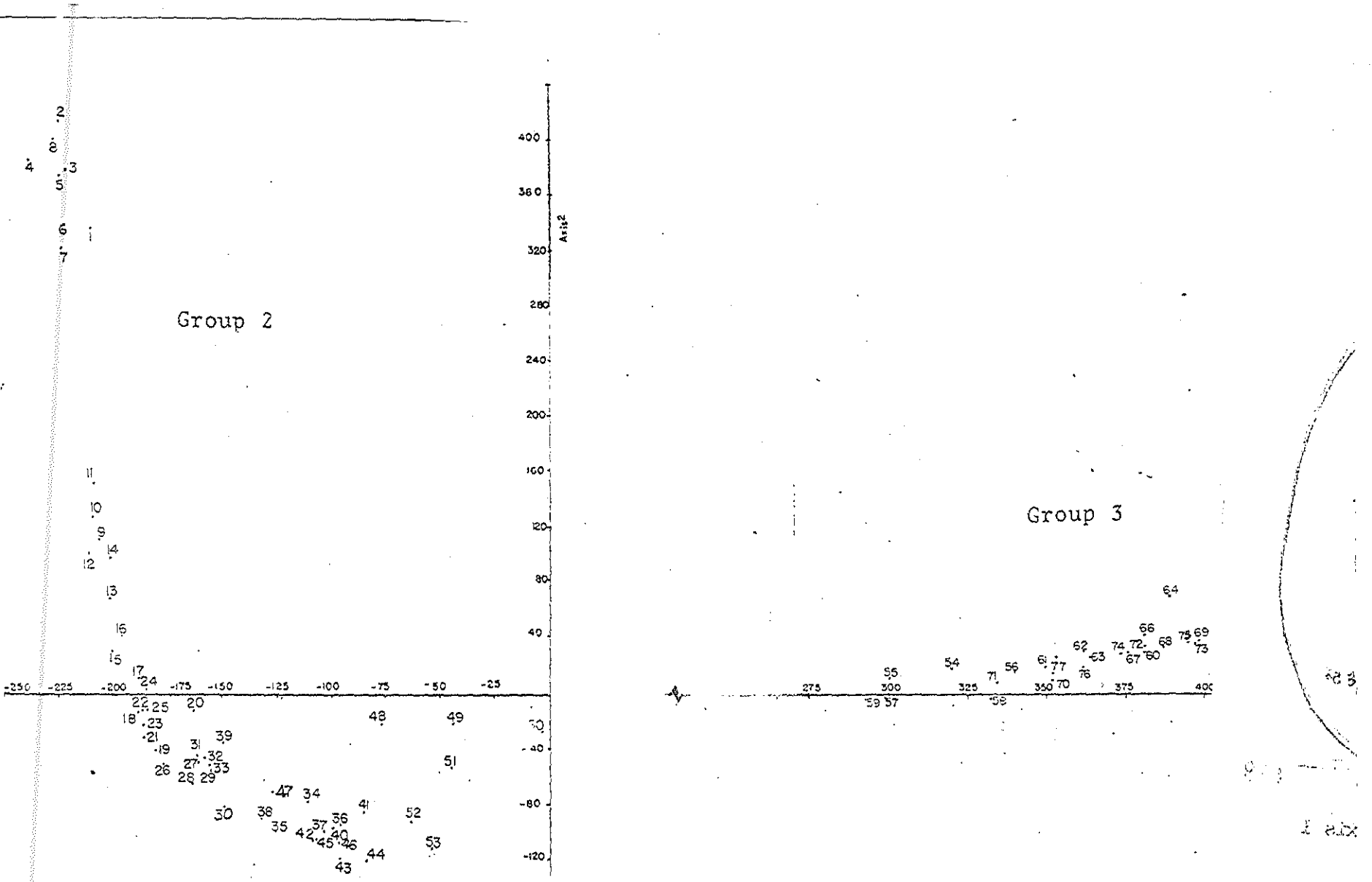


Fig.4: Reciprocal averaging ordination diagram of the stands (Each number in the diagram corresponds to a stand.)

#### 4.2.1 Ordination of Group 2 Stands

The ordination scores of group 2 stands are given in Appendix D2. The indicator species that were identified by the two-way indicator species analysis are represented by symbols for each stand position in Figure 7. The groups of the stands that were identified by the indicator species were also shown on the stands ordination diagrams and the stands that belonged to the same group came out close together in most cases.

Superimposing the values of the environmental factors determined for each stand on the detrended correspondence analysis ordination diagrams (Fig. 8-17) revealed that the stands were distributed on the first axis along a moisture gradient. The stands with high ordination scores had the lower altitudes and were drier than the stands with low ordination scores which had higher altitudes. The other environmental factors were also seen to show some pattern with different degrees of skewness along the first axis. For instance, organic matter and magnesium were seen to decrease along the first axis while sodium and conductivity show a trend of increase along the first axis. The cations Ca and K are seen to be high at both the right and left ends of the ordination diagrams with lower values in between.

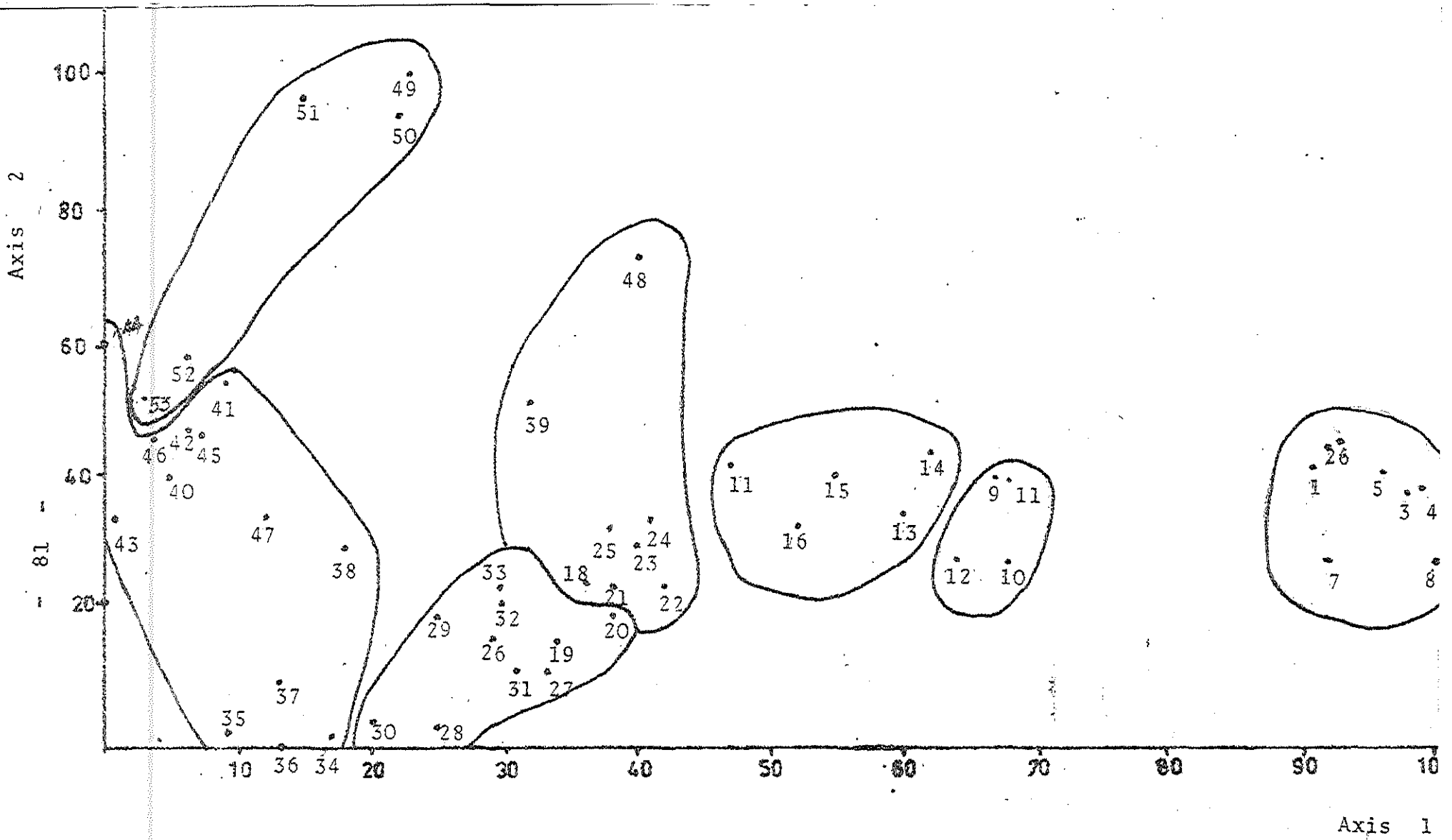


Fig.5: Detrended correspondence analysis ordination diagram of group 2 stands. (Each number corresponds to a stand and each letter to the stand group of the two-way indicator species analysis).

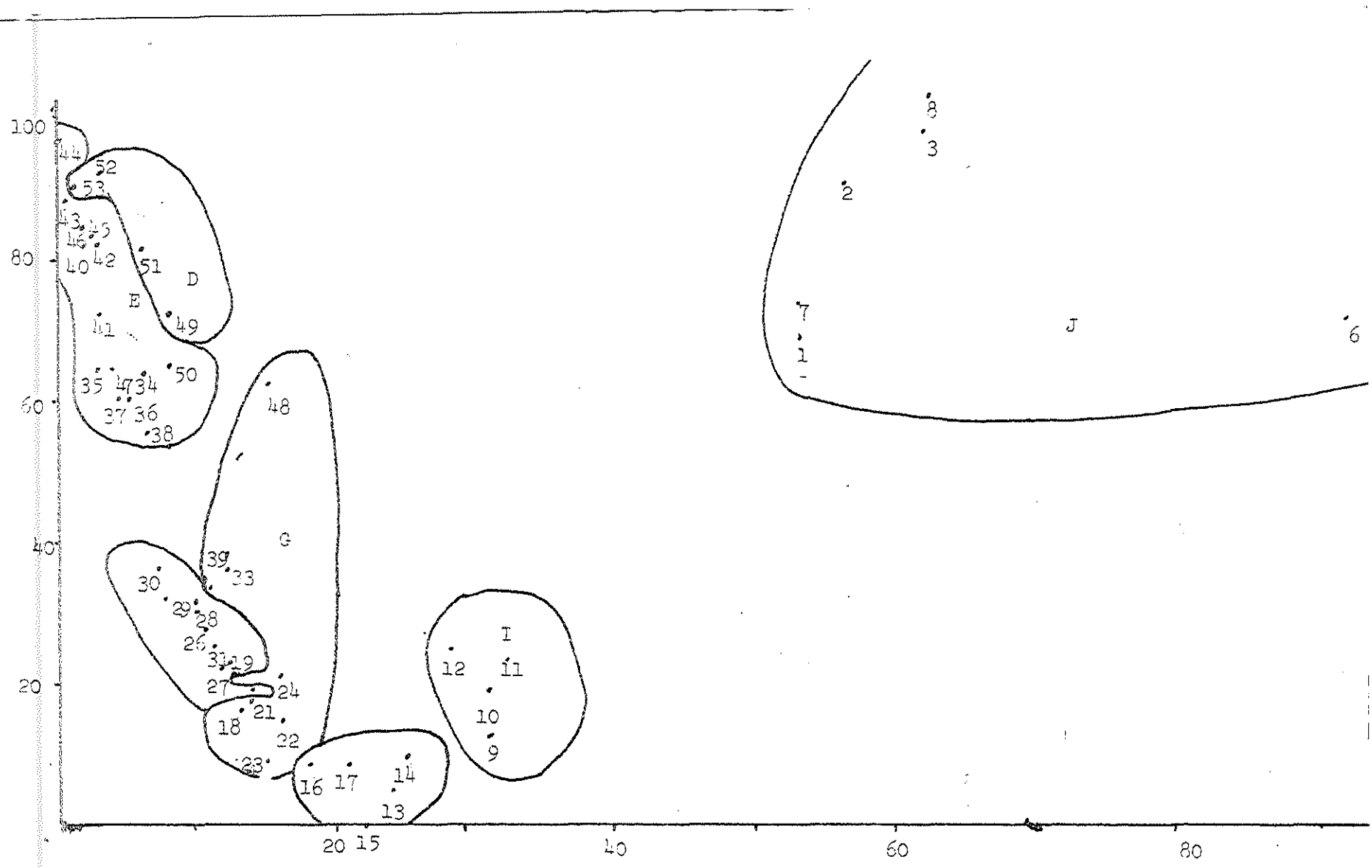


Fig. 6 Reciprocal-averaging ordination diagramme of group 2 stands (Each number corresponds to a stand and each letter to the stand group of the two way indicator species analysis).

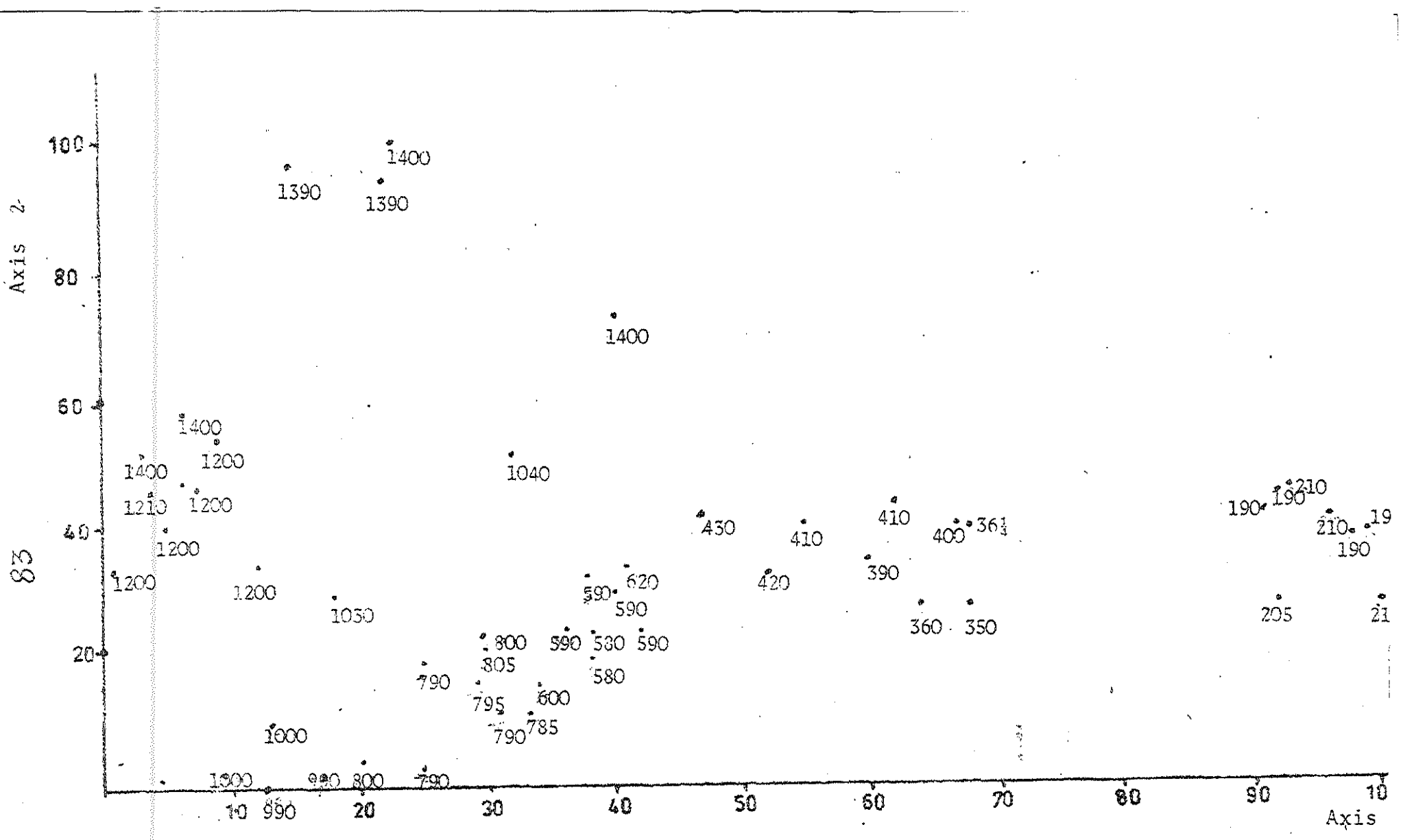


Fig. 8 Detrended correspondence analysis ordination diagram of group 2 stand with the altitude of the stands (meters above sea level) superimposed.

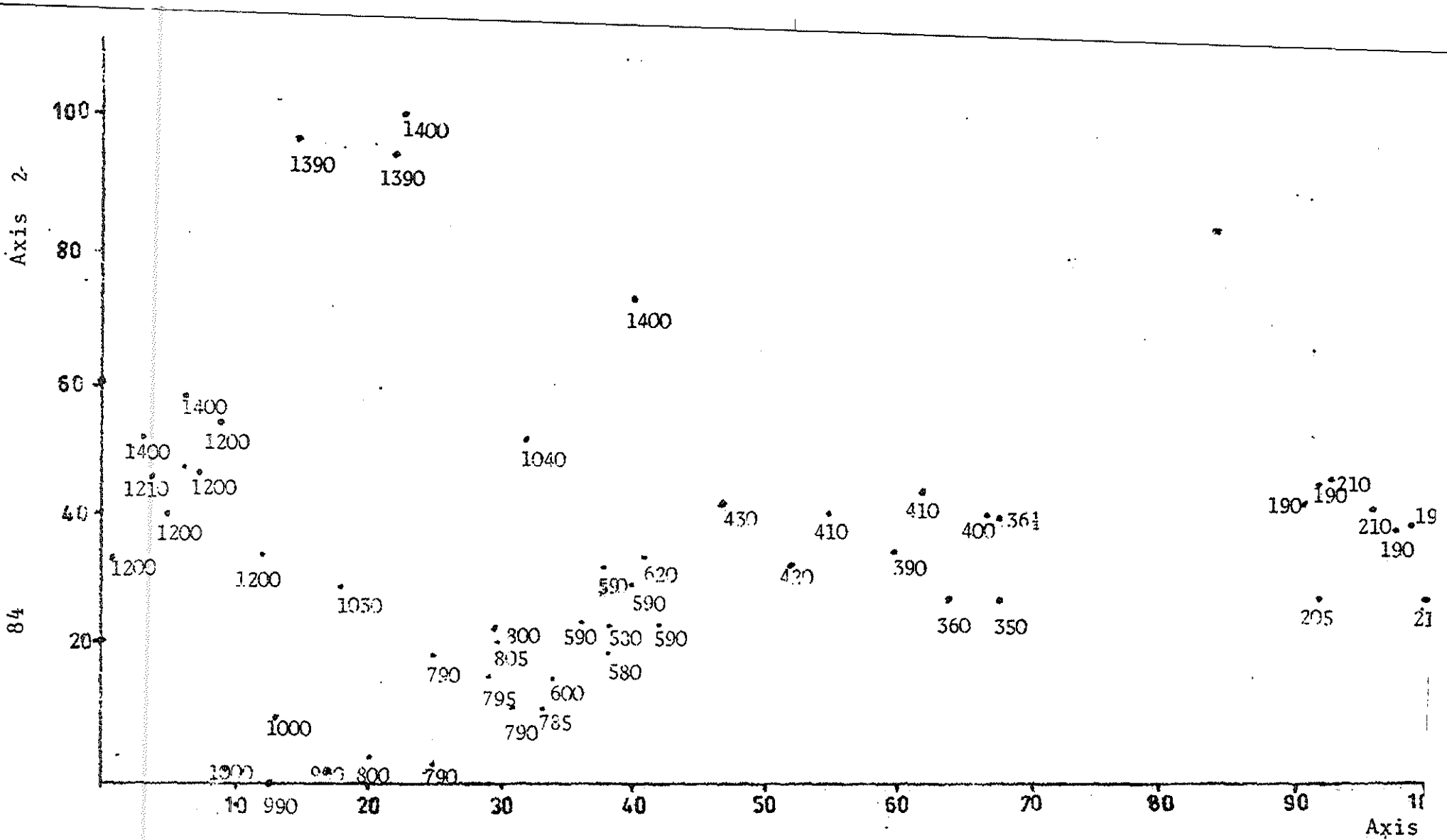


Fig. 8 Detrended correspondence analysis ordination diagram of group 2 stand with the altitude of the stands (meters above sea level) superimposed.

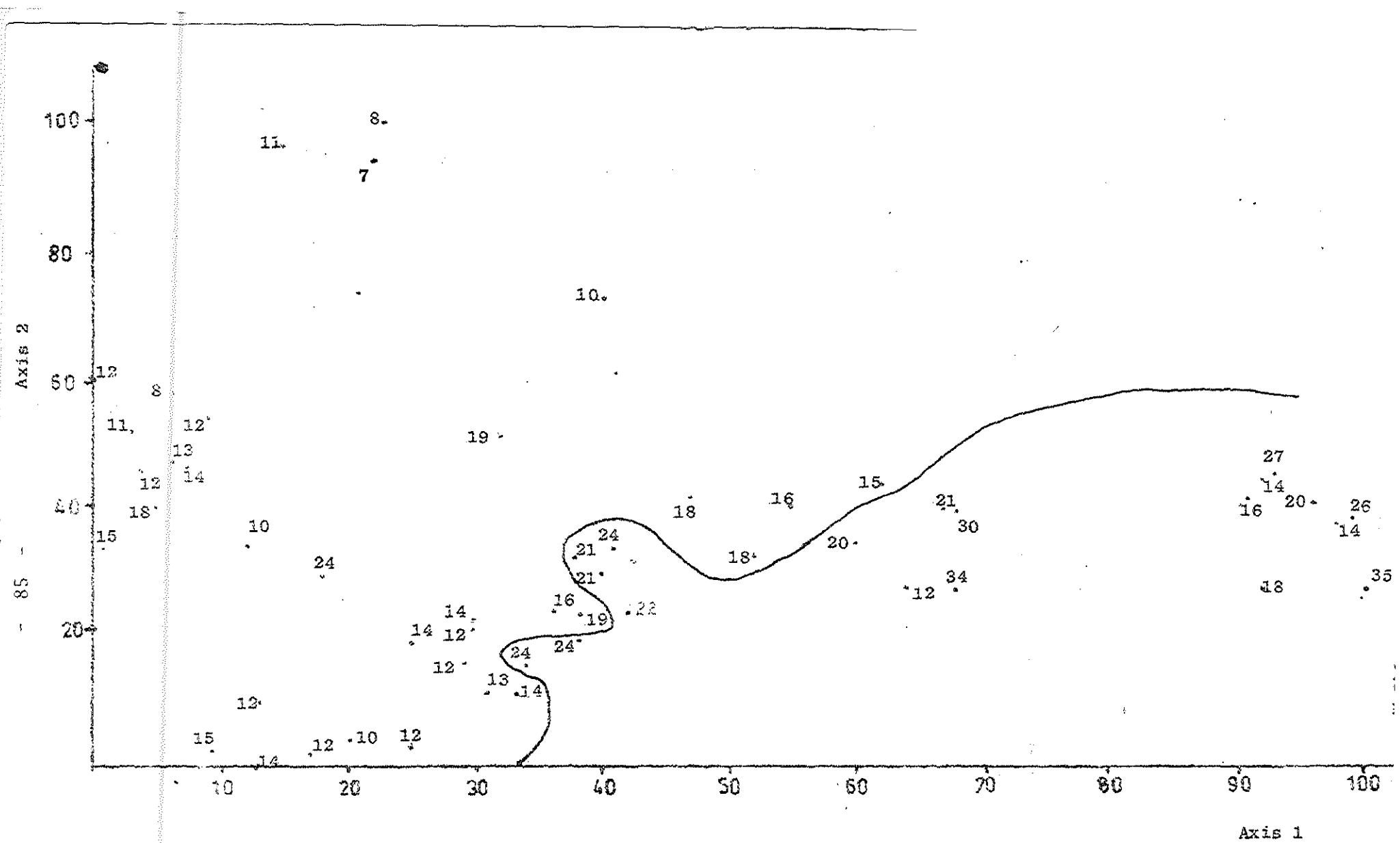


Fig. 9 Detrended correspondence analysis ordination diagram of group 2 stands with the % of silt averaged over all the depth superimposed

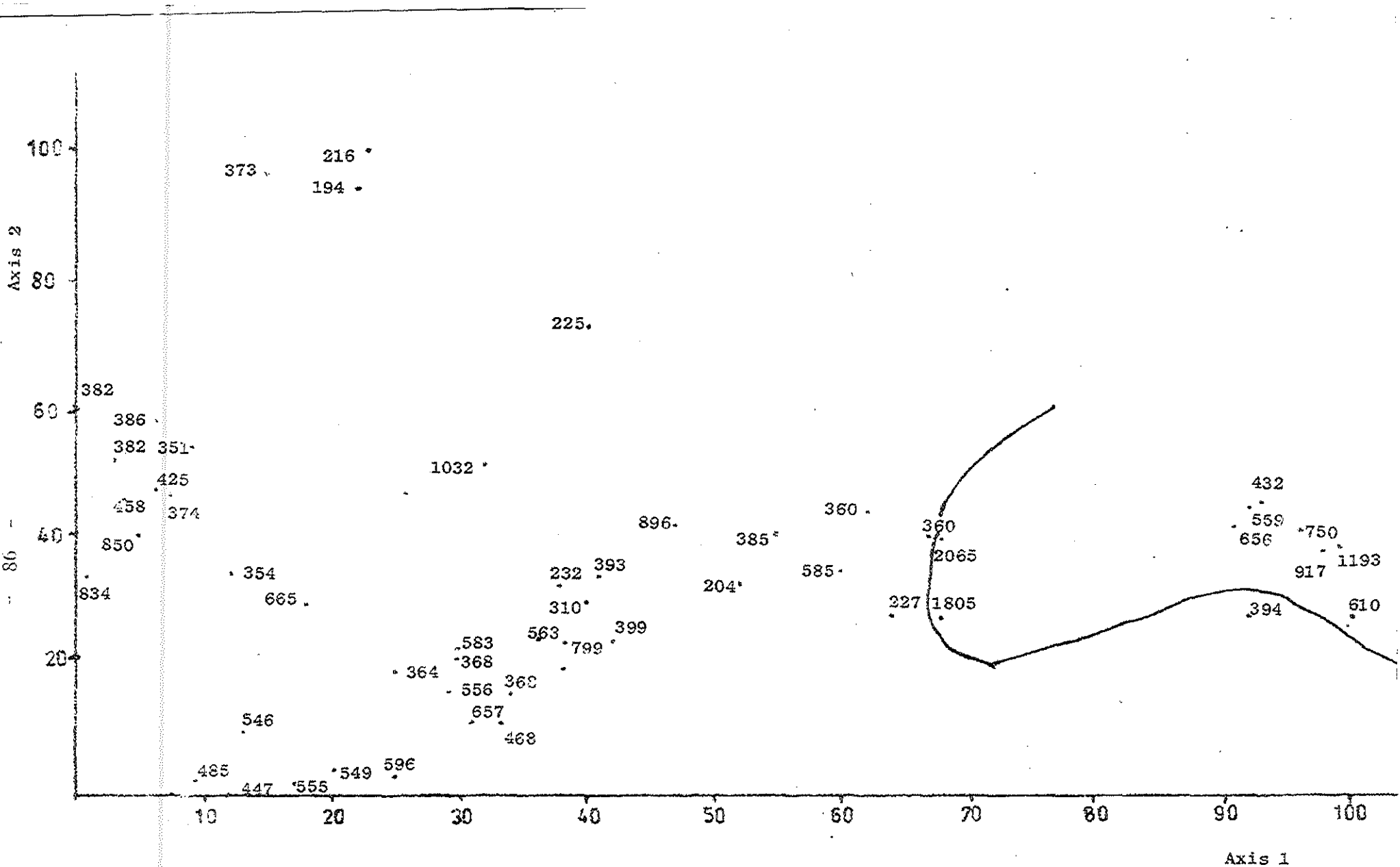


Fig.10 Detrended correspondence analysis ordination diagram of group 2 stands with the % of clay averaged over all the depth  $\times 10^{-2}$  superimposed

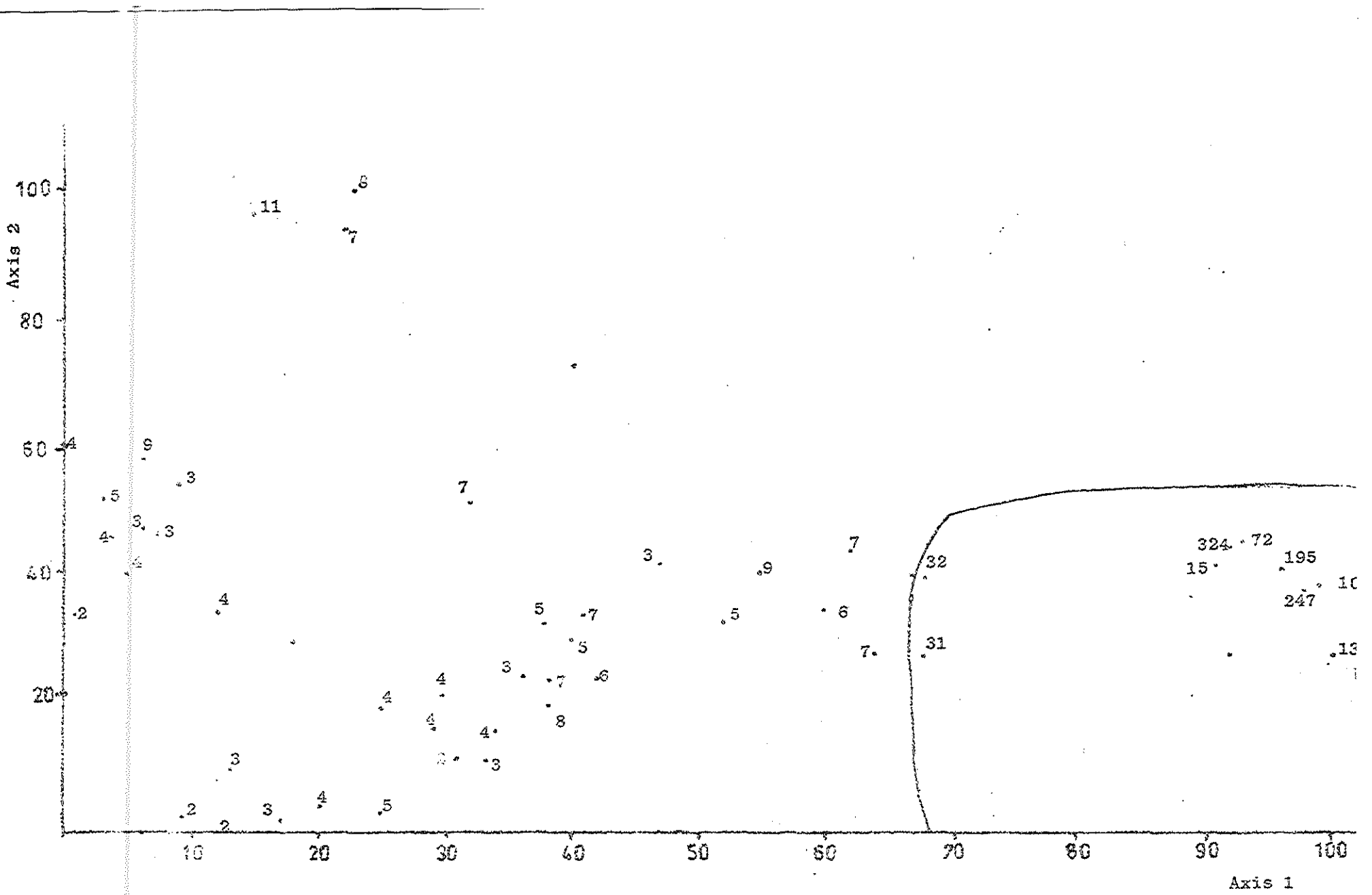


Fig. 11 Detrended correspondence analysis ordination diagram of group 2 stands with the value of conductivity averaged over all the depth ( $\text{mmhos/cm} \times 10^{-2}$ ) superimposed

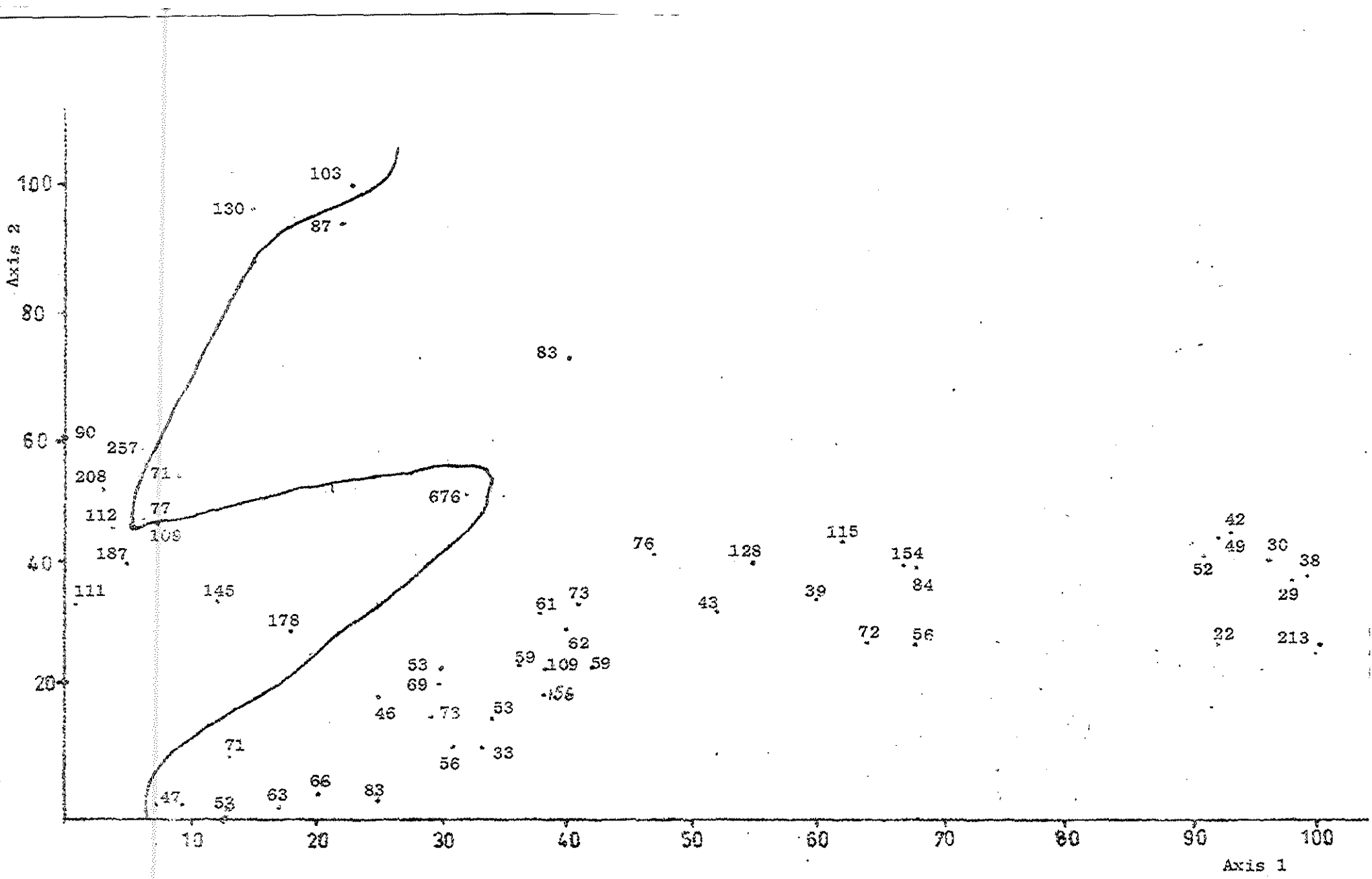


Fig. 12 Detrended correspondence analysis ordination diagram of group 2 stands with the % of organic matter averaged over all the depth superimposed

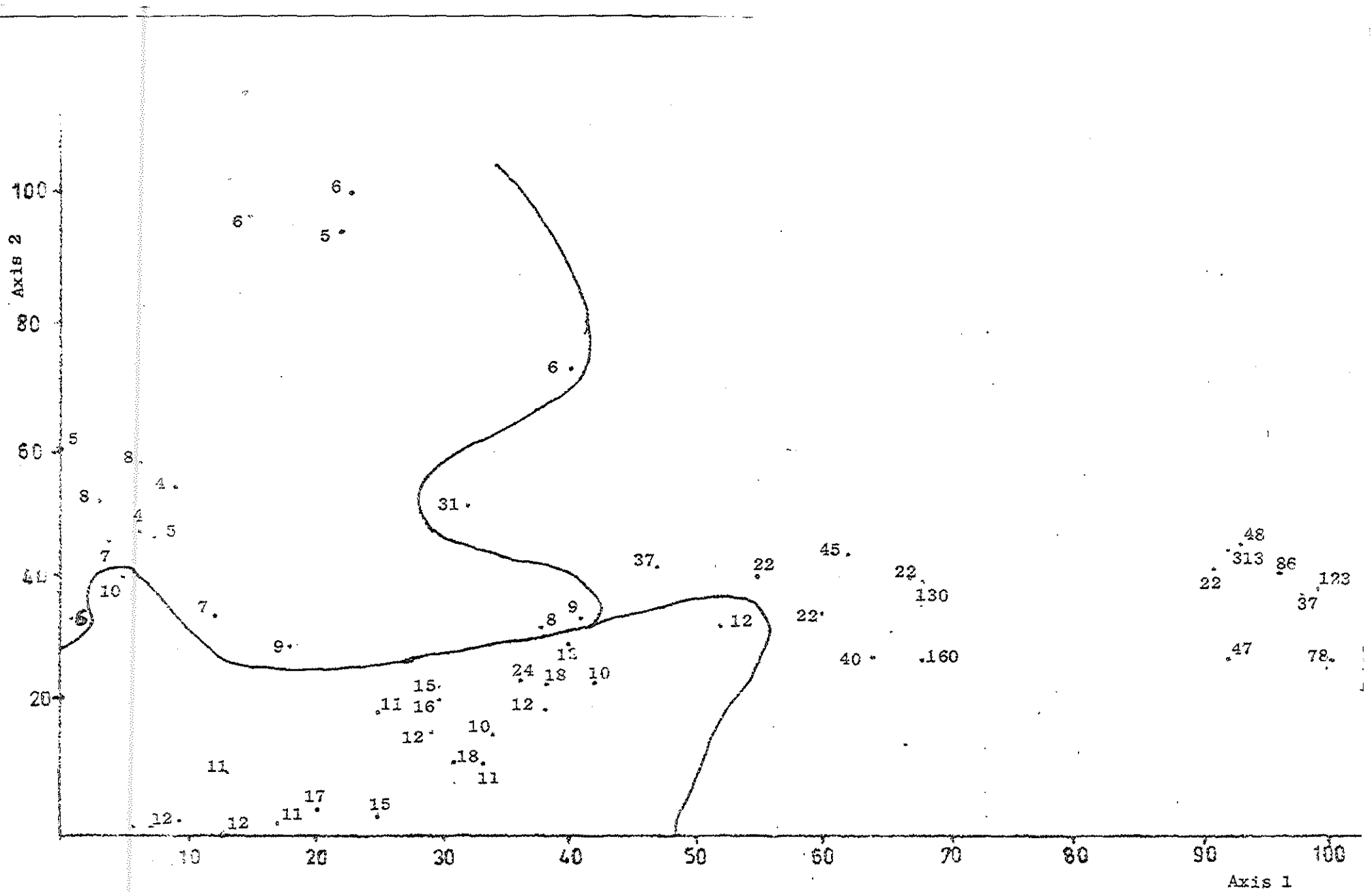


Fig. 13 Detrended correspondence analysis ordination diagram of group 2 stands with the values of K averaged over all the depth (meq/100g soil  $\times 10^{-2}$ ) superimposed

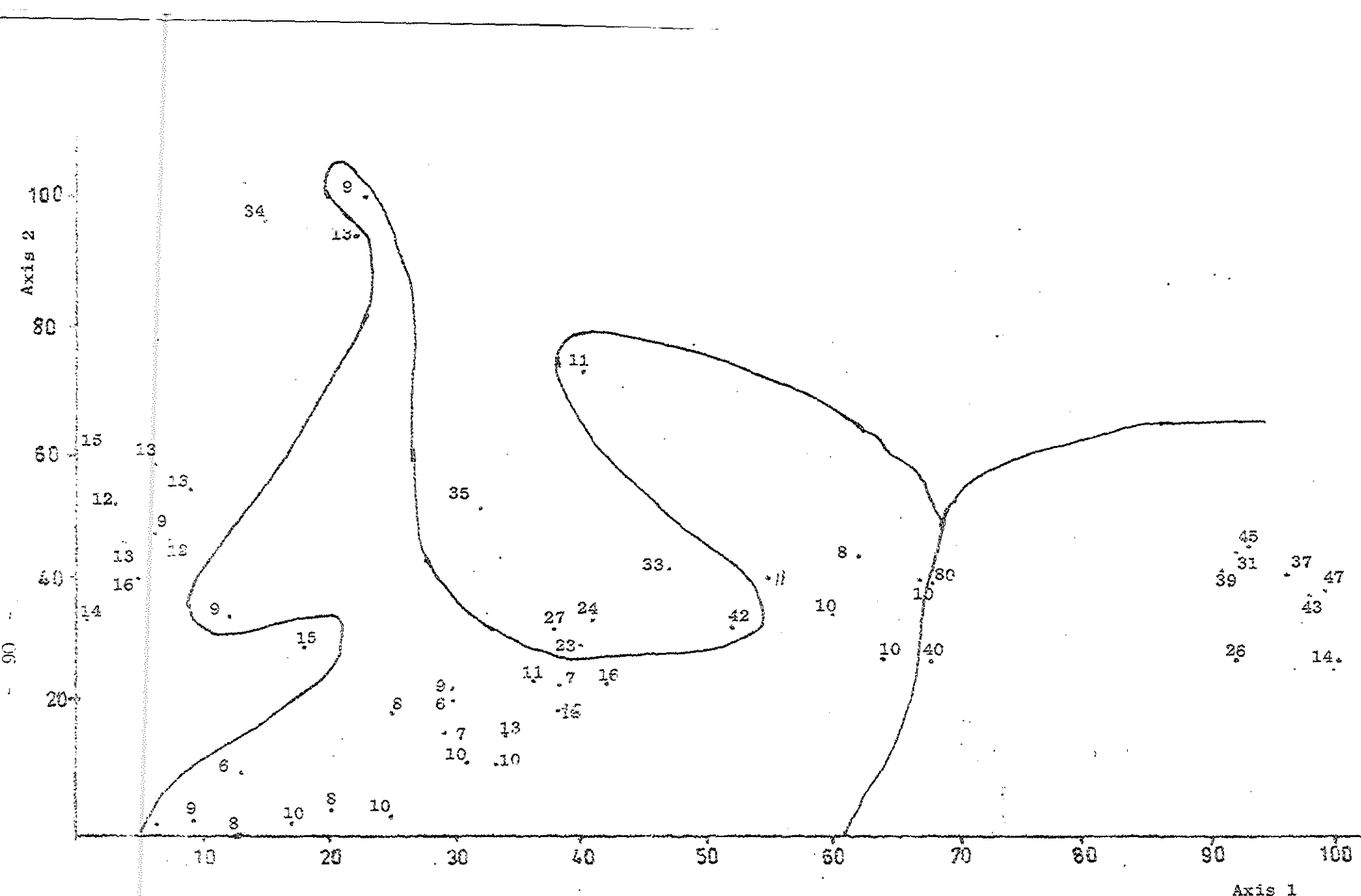


Fig.14 Detrended correspondence analysis ordination diagram of group 2 stands with the values of Ca averaged over all the depth (meq/100g soil x 10<sup>2</sup>) superimposed

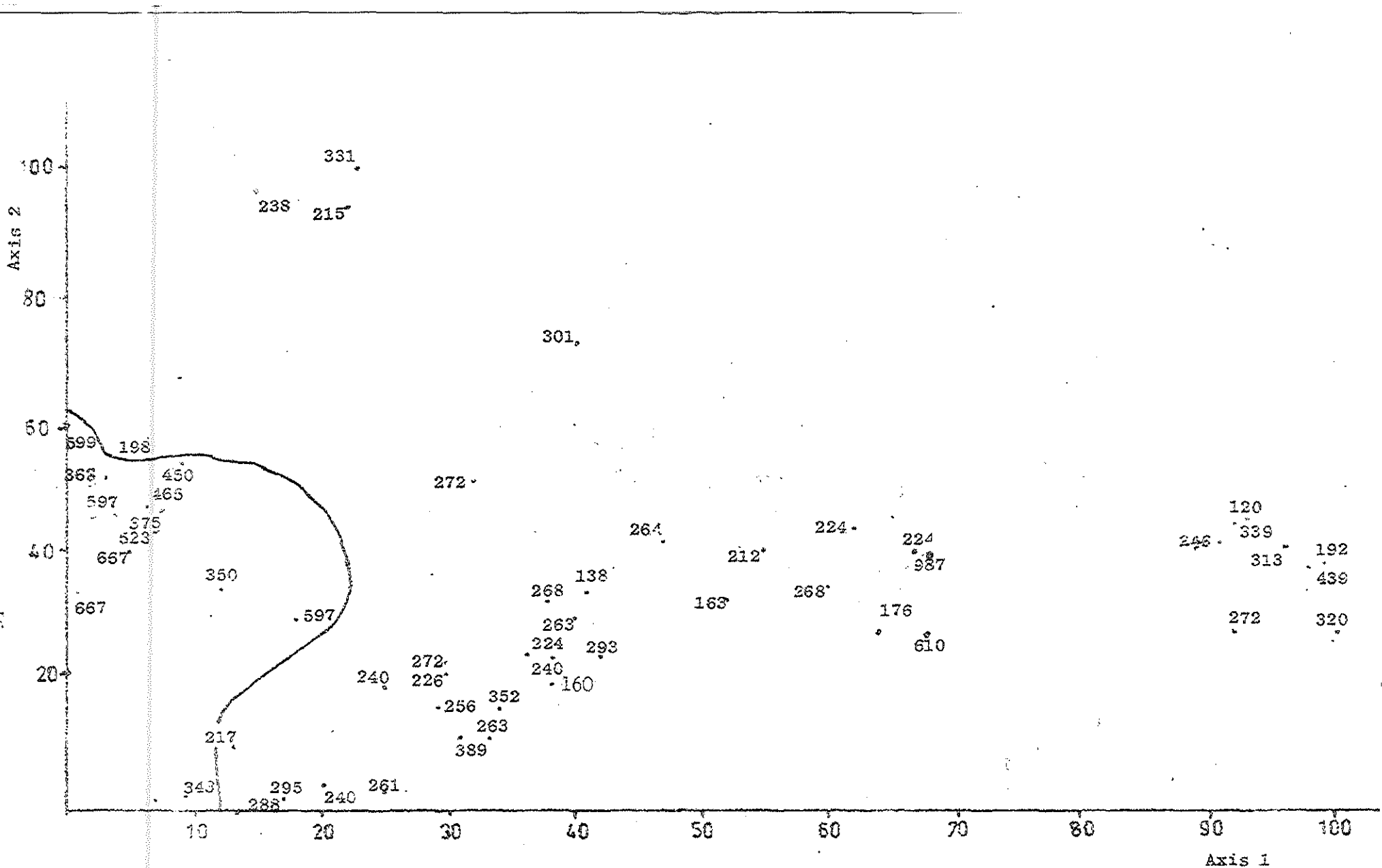


Fig. 15 Detrended correspondence analysis ordination diagram of group 2 stands with the values of Mg averaged over all the depth (meq/100g soil x 10<sup>-2</sup>) superimposed

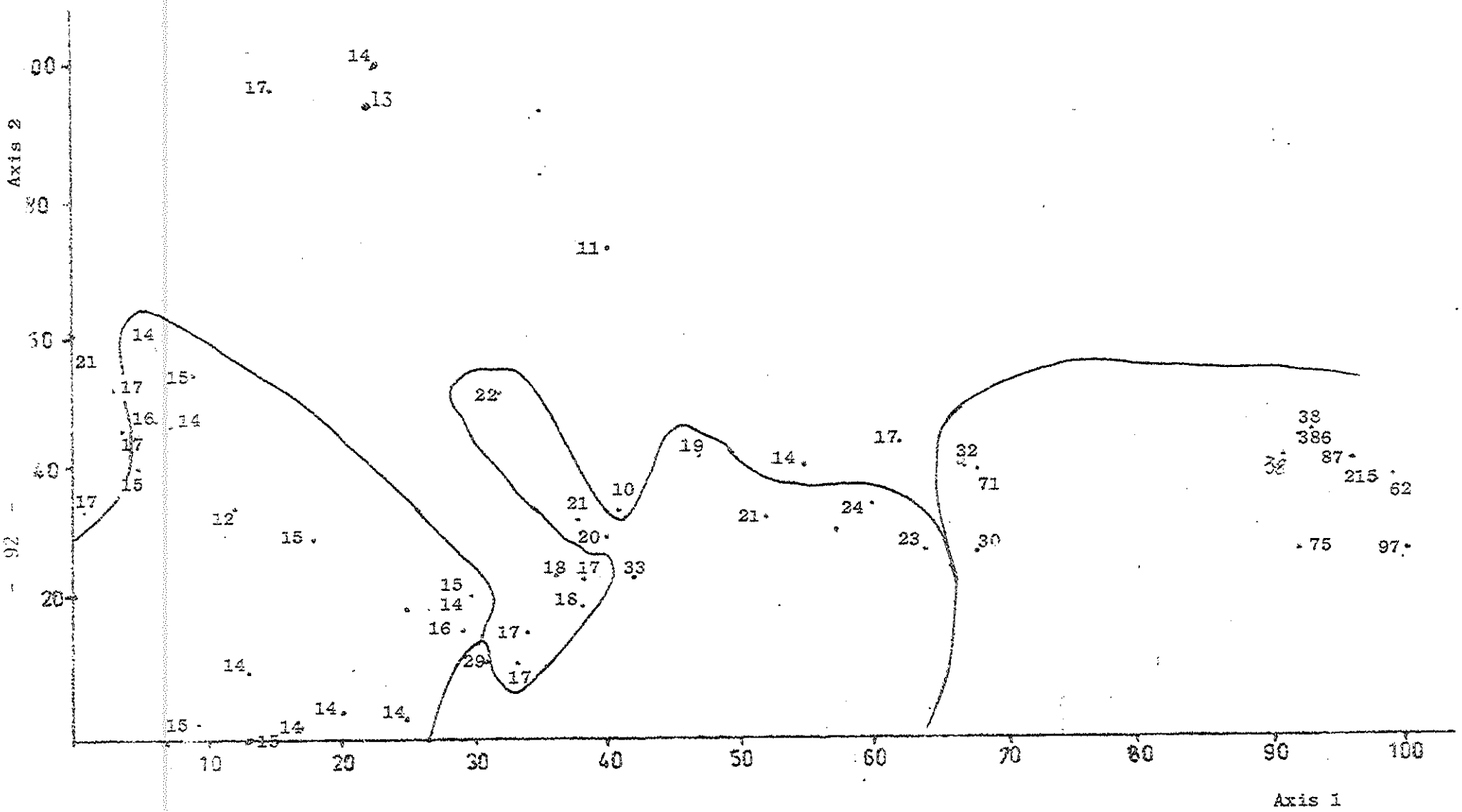


Fig. 16 Detrended correspondence analysis ordination diagram of group 2 stands with Na averaged over all the depth (meq/100g soil) superimposed

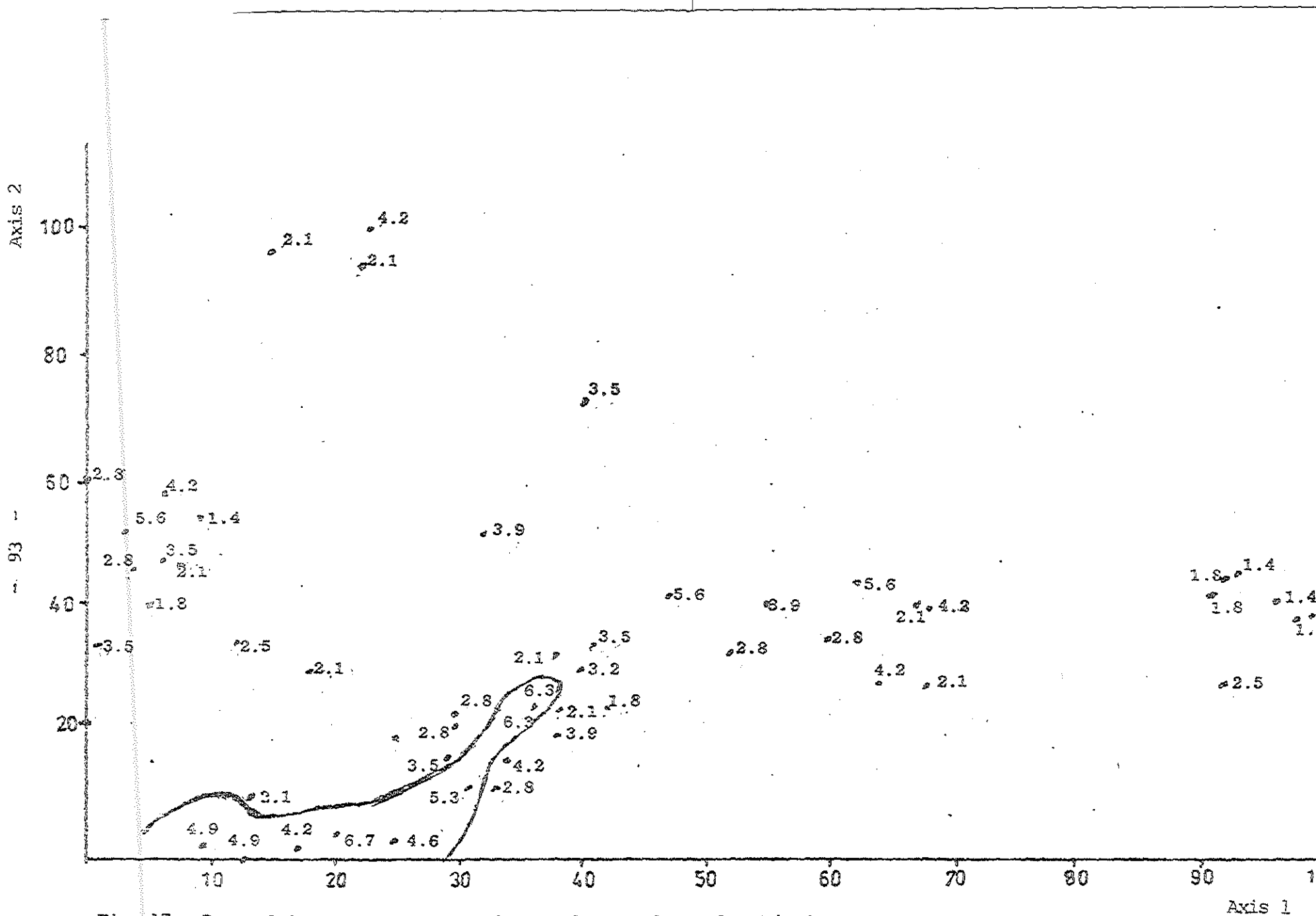


Fig. 17: Detrended correspondence analysis of group 2 stands with the values of MN of the surface soils Superimposed.

The positive correlation between the amounts of organic matter and altitude may be attributed to the increasing moisture with increasing altitude creating better conditions for plant growth and a greater diversity of plants. As a result of the high organic matter at high altitudes, high concentrations of the cations calcium and potassium were observed. The high values of the cations calcium and potassium in the lower altitudes may be attributed to the higher clay contents and more arid conditions prevailing resulting in less loss through leaching.

The cation, magnesium, is also observed to be high in the soils of the high altitude stands which have soils with higher organic matter contents. Although it is indicated that magnesium content of organic soils is not very different from overall soil mineral content (Buckman and Brady, 1974) the correlation between high organic matter and high magnesium contents suggested that this element had been actively accumulated in the plant biomass which in turn enriched the soil with magnesium upon death and decay.

Soil conductivity and the cation sodium showed a trend of increase along the first axis. This could be explained by the increasing aridity with decreasing

altitude resulting in higher accumulation of the minerals in the soils because little had been lost through leaching and the increasing effects of the sea. These higher concentrations of the cations and higher clay contents of the soils in the low altitude stand also resulted in higher pH values.

Detrended correspondence analysis weighted averages hybrid ordination scores are given in Appendix D4. These results supported the finding from classification as well as those obtained by superimposing the values of environmental factors of each stand on the stands ordination diagrams. In this detrended correspondence analysis weighted averages hybrid ordination (Fig. 18), soil conductivity and the cations sodium and potassium have high ordination scores in the first axis. This coincided with the high ordination scores of the low altitude arid stands. On the other hand, organic matter and elevation have low ordination scores in the first axis. The high altitude and relatively more humid stands also have low scores on this axis.

#### 4.2.2 Ordination of Group 3 Stands

Ordination scores for group 3 stands are given in Appendix D3. As in the case with the group 2 stands

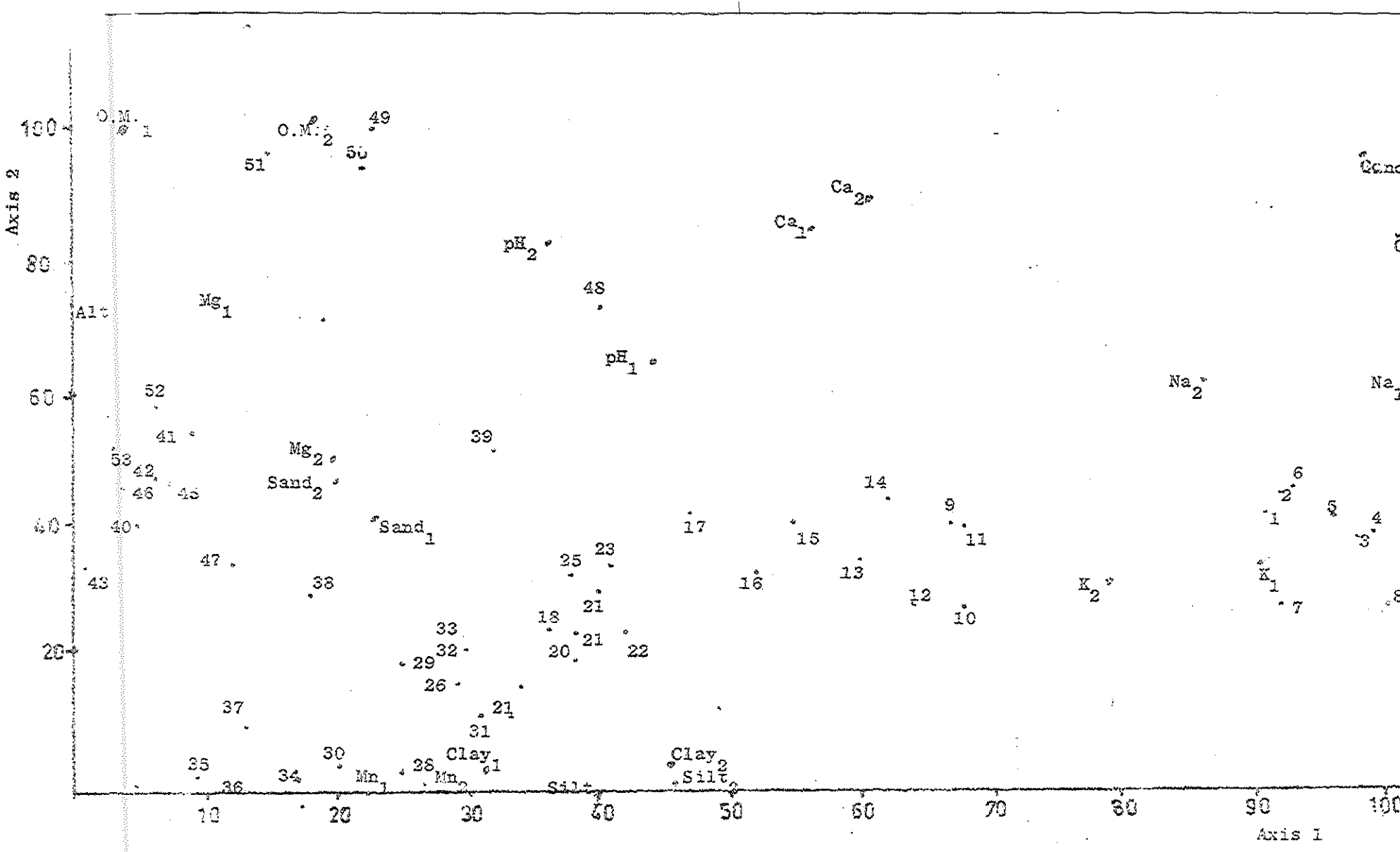


Fig. 18 Environmental factors ordinated with the group 2 stands according to detrended correspondence analysis weighted averages ordination hybrid. (Each number corresponds to a stand and the environmental factors with a suffix 1 represent surface values, and those with suffix 2 are average values over all the depth. Cond = conductivity, O.M. = organic matter and Alt = altitude)

the stands in group 3 that were related according to their classification came out close together in the stands ordination diagrams. (Fig. 19 and 20).

Superimposing the values of the environmental variables on the ordination diagrams (Fig. 22-23) revealed that the stands were spread along the first axis according to the organic matter content of their soils. The stands with high organic content have low ordination scores, and stands with low organic matter content have high ordination scores. As has been indicated in the discussion on classification, the high organic matter was related to high soils moisture on the region, thus the stands could be said to be distributed in the ordination diagram along a moisture gradient. The other environmental factors did not show clear patterns in either of the first or second axes, but soil conductivity and cations Ca and K were observed to be high in the stands at the left and right end of the ordination diagram, being medium in the stands at the middle of the ordination diagram. The high calcium and potassium amounts in the soils could be attributed to the high organic matter content of the soils in the stands with low first axis ordination. High organic matter content in the soils increased the cation adsorbing capacity

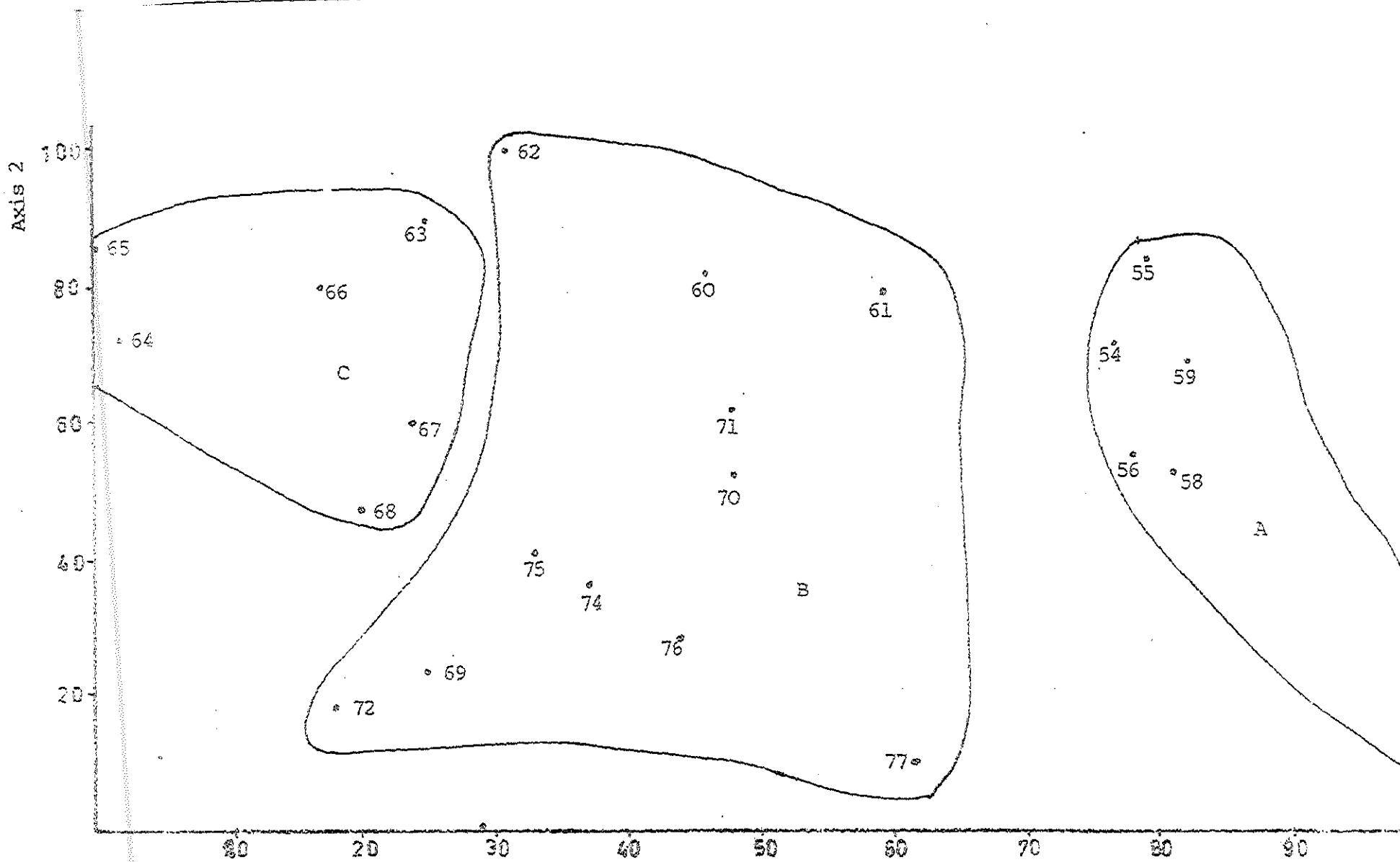


Fig 19: Detrended correspondence analysis ordination diagram for group 3 stands  
 (each number correspondece to a stand and the letters to a stand group)

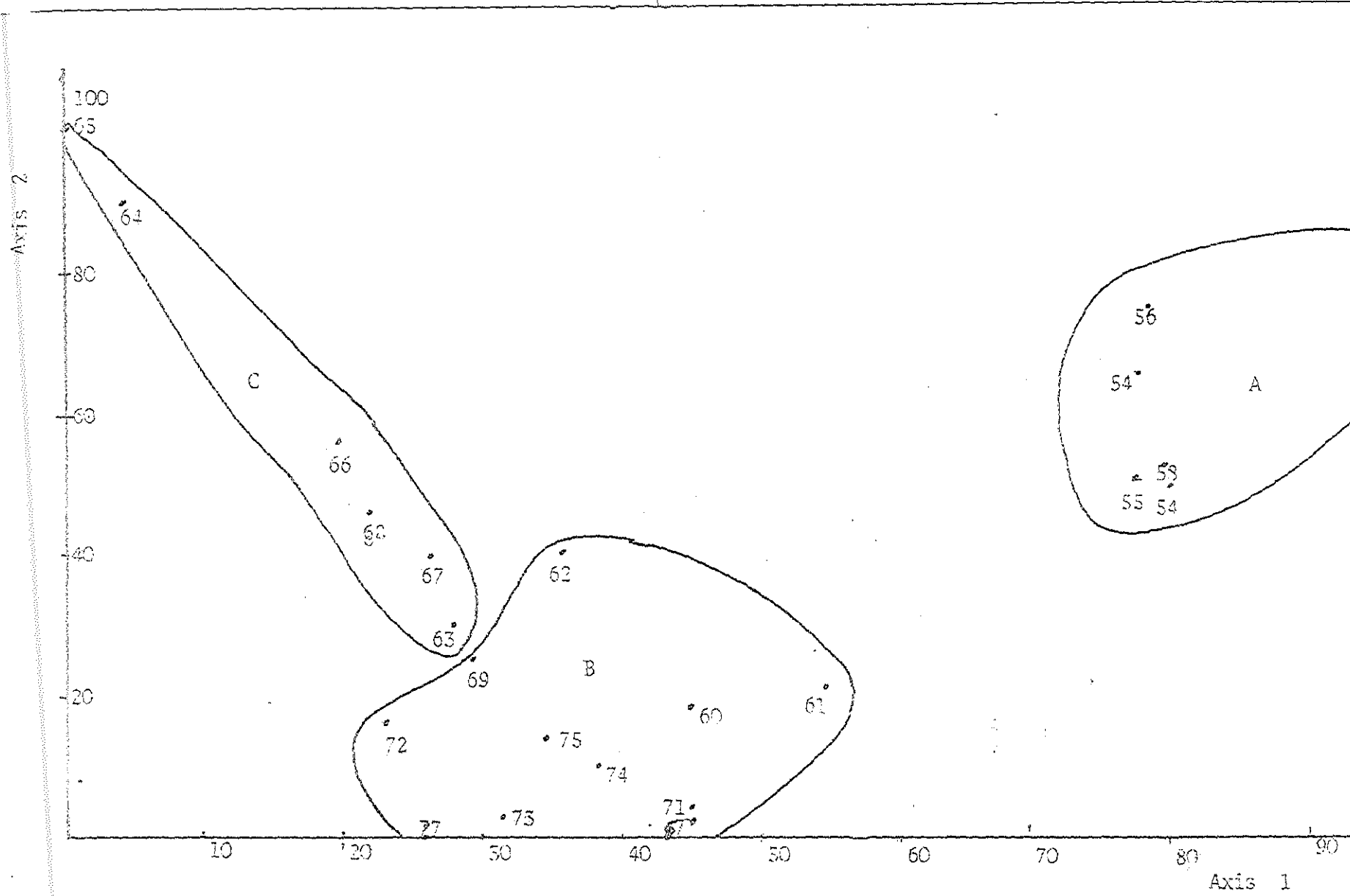
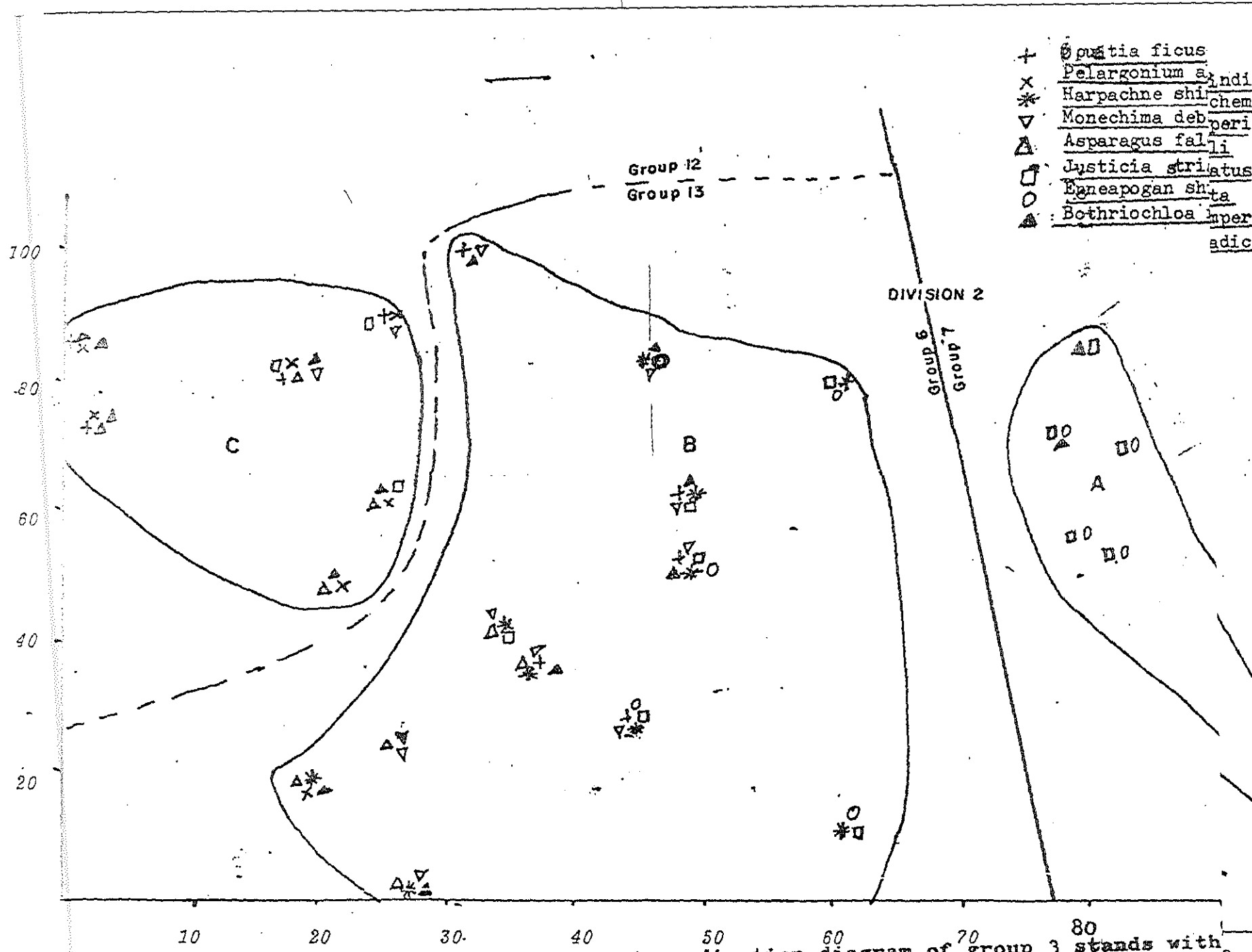


Fig. 20 Reciprocal averaging ordination diagram of group 3 stands (Each number corresponds to a stand and each letter to the stand group of the two indicator species analysis)

Axis 1

Axis 2



- + *Opuntia ficus*
- x *Pelargonium andi*
- \* *Harpachne shir*
- ▽ *Monechima deb*
- △ *Asparagus fal*
- *Jysticia striatus*
- *Equeapogan sh*
- ▲ *Bothriochloa spere*

Fig.21 Detrended correspondence analysis ordination diagram of group 3 stands with the indicator species identified by the species list.

10 20 30 40 50 60 70 80 90 100  
 Axis

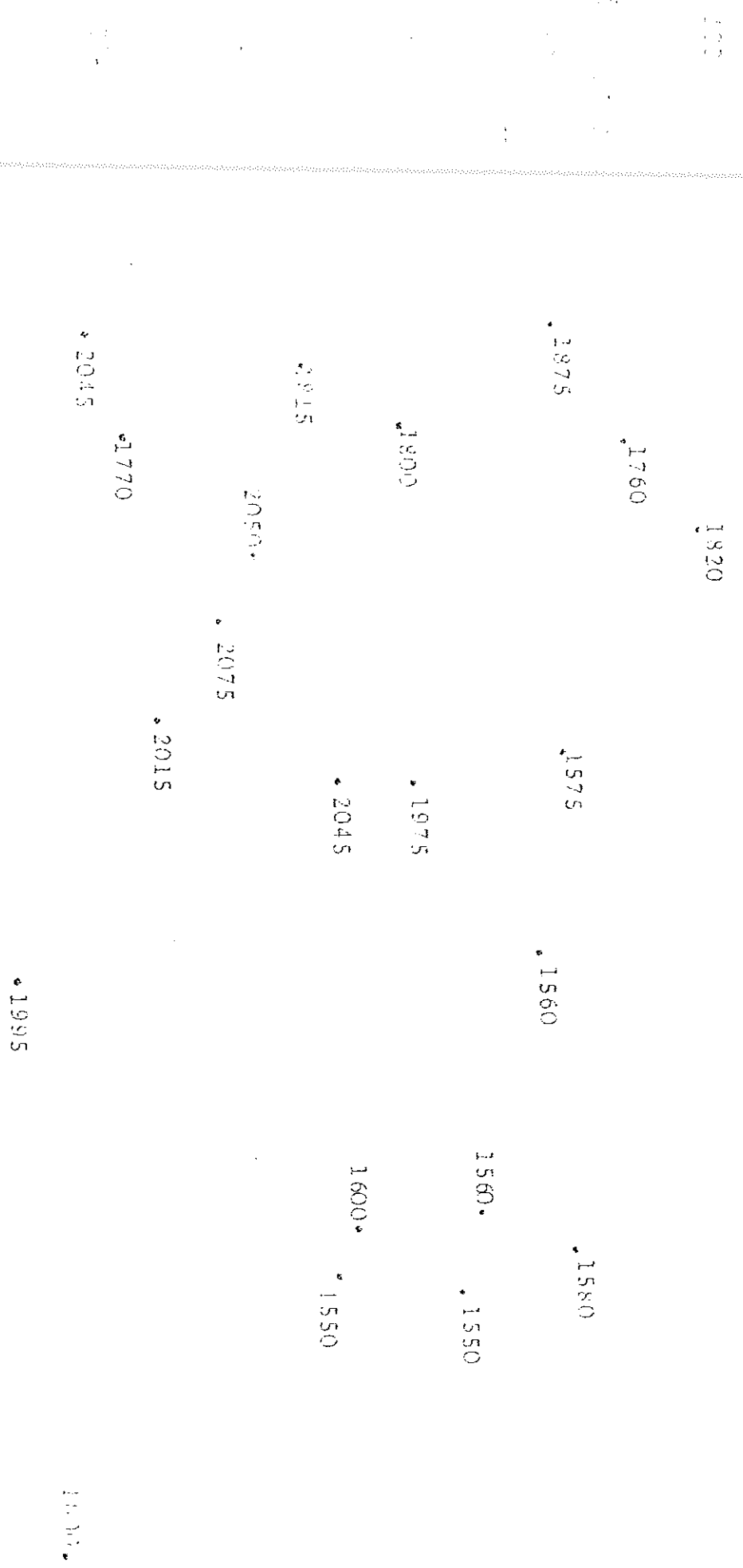


Fig. 22 Detrended correspondence analysis ordination diagram of group 3 stands with the altitude meter of the stands superimposed

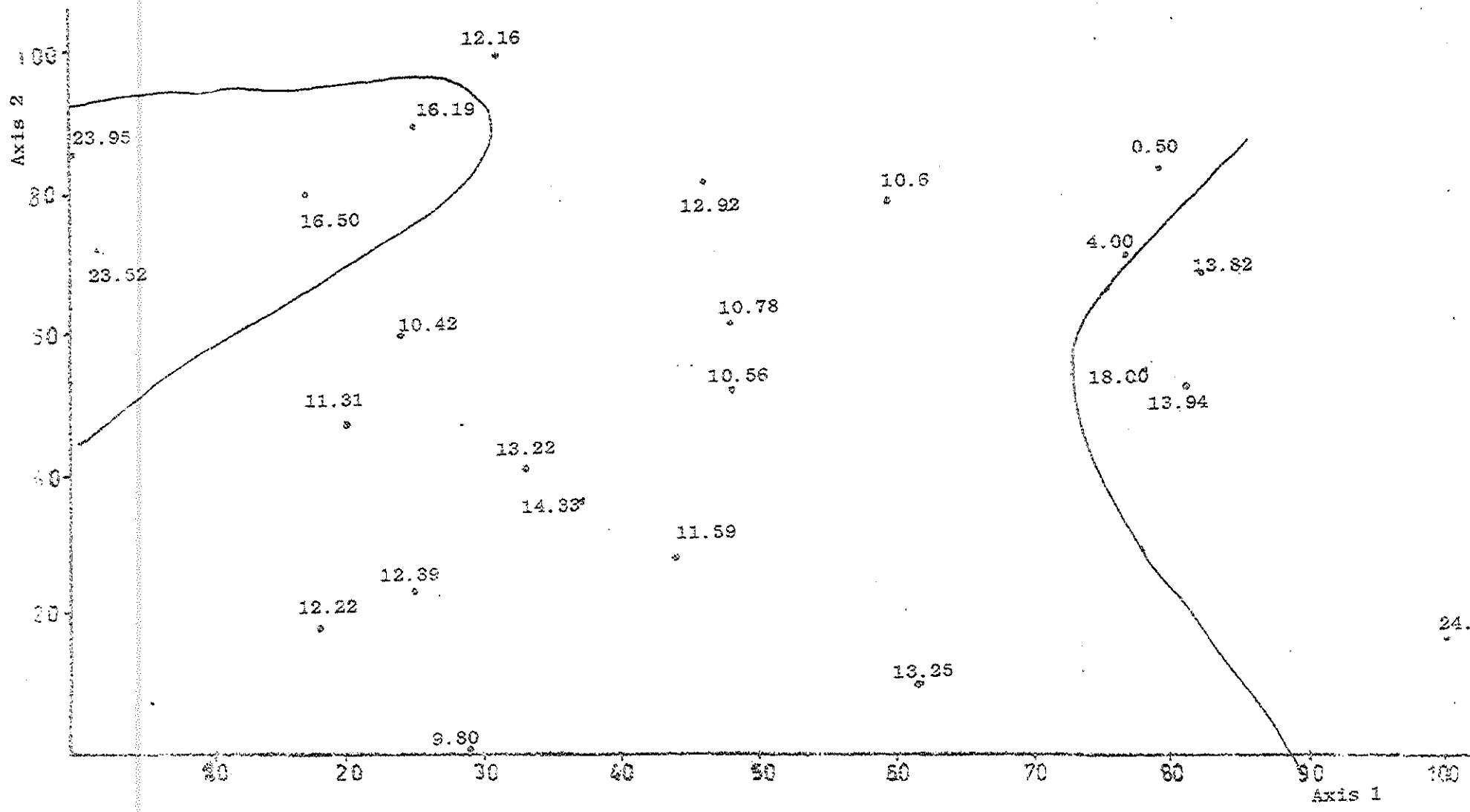


Fig. 23 Detrended correspondence analysis ordination diagram of group 3 stands with the % of silt averaged over all the depth superimposed

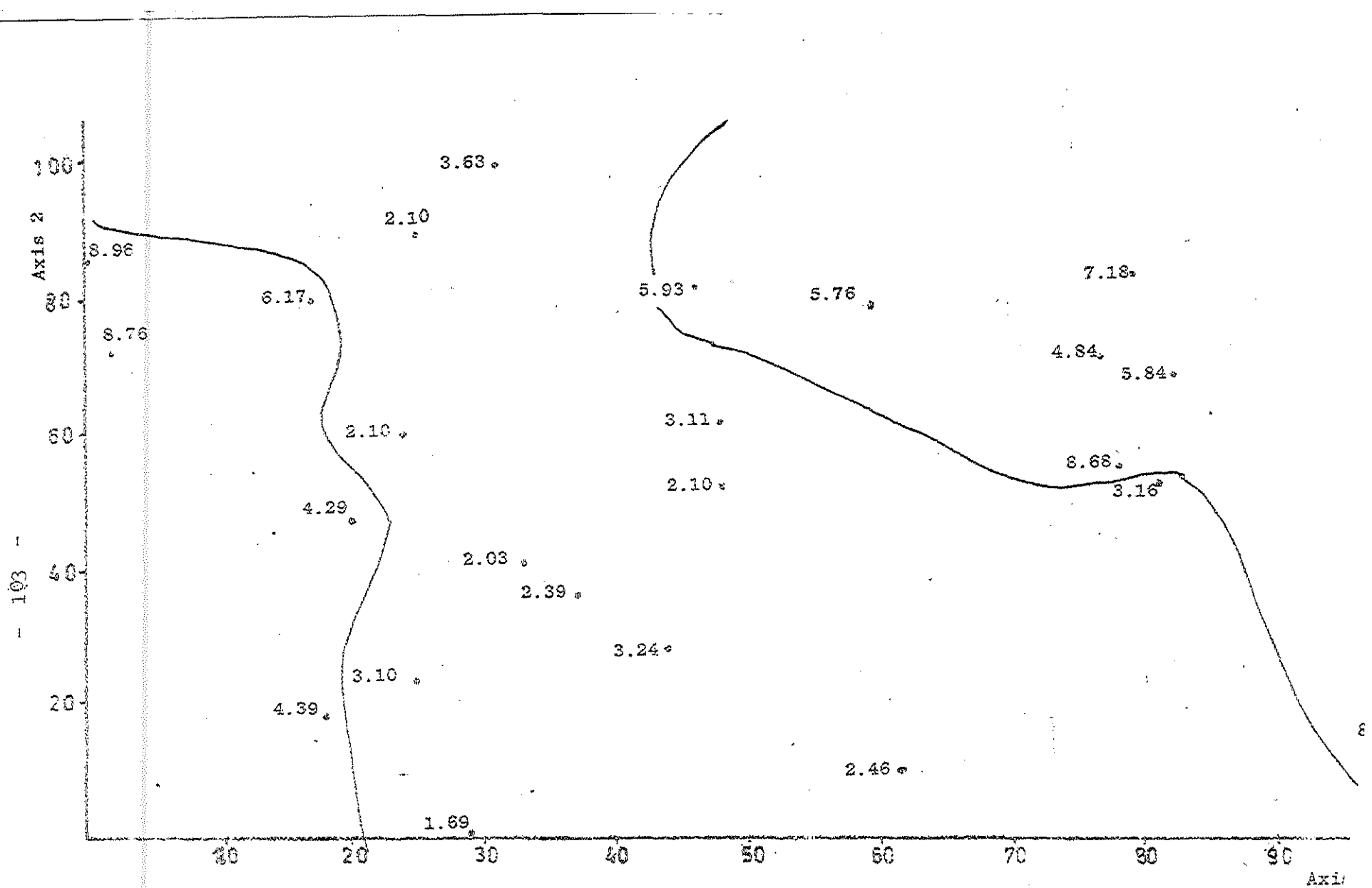


Fig.24 Detrended correspondence analysis ordination diagram of group 3 stands with the % of clay averaged over all the depth superimposed

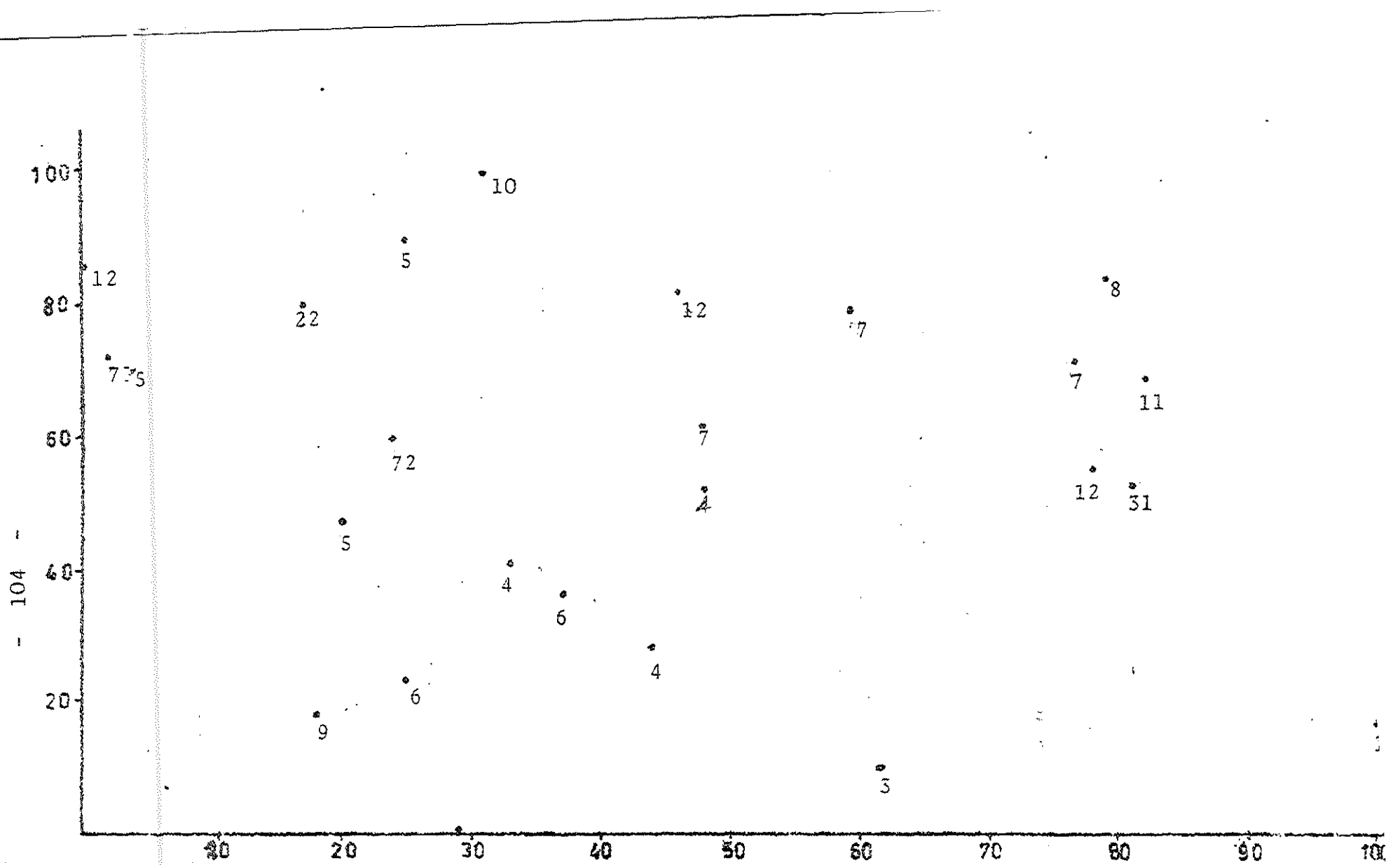


Fig. 25 Detrended correspondence analysis ordination diagram of group 3 stands with conductivity of the surface soils (mm hos/cm x 10<sup>-2</sup>) superimposed.

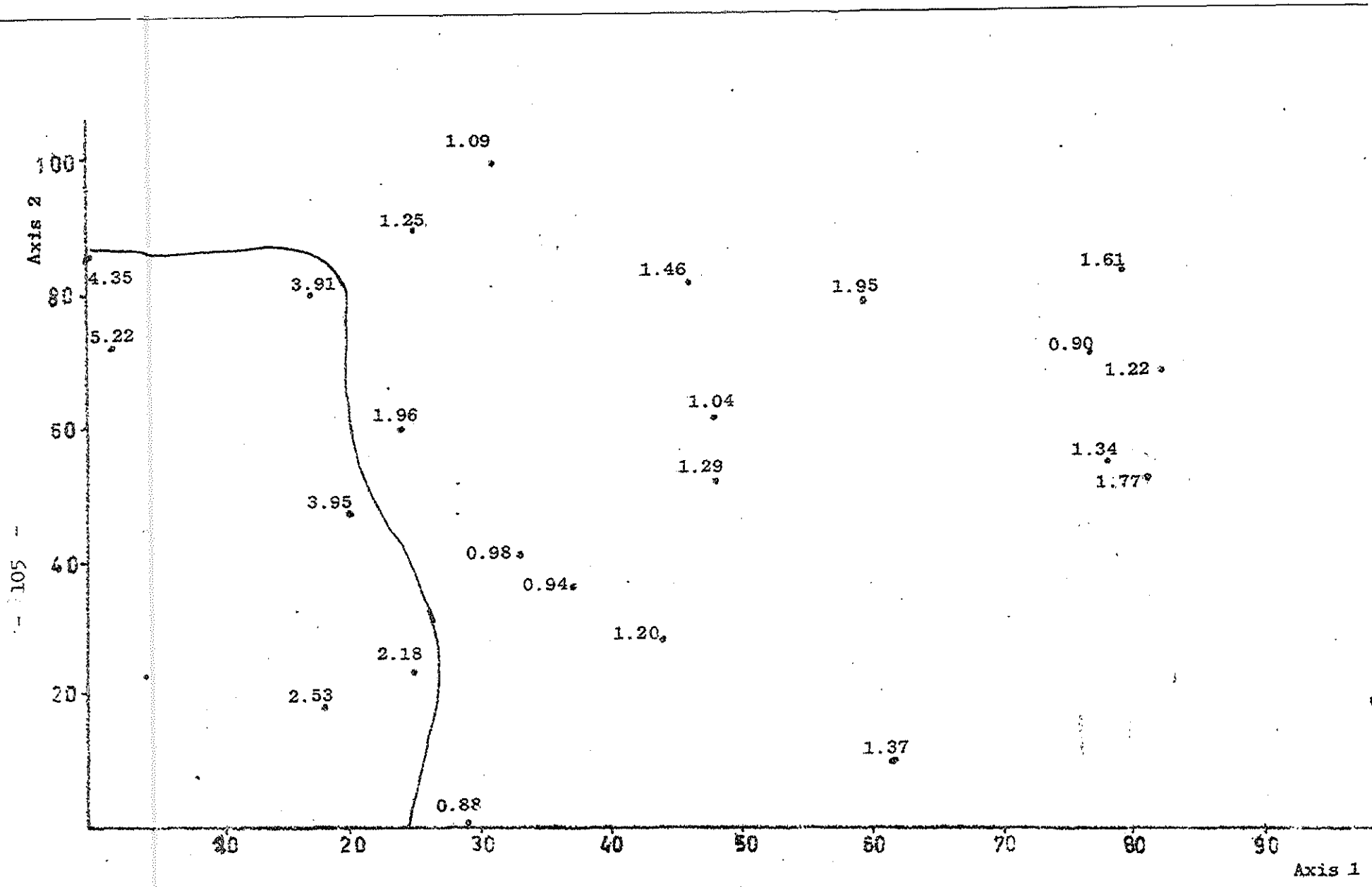


Fig. 26 Detrended correspondence analysis ordination diagram of group 3 stands with the % of organic matter averaged over all the depth superimposed

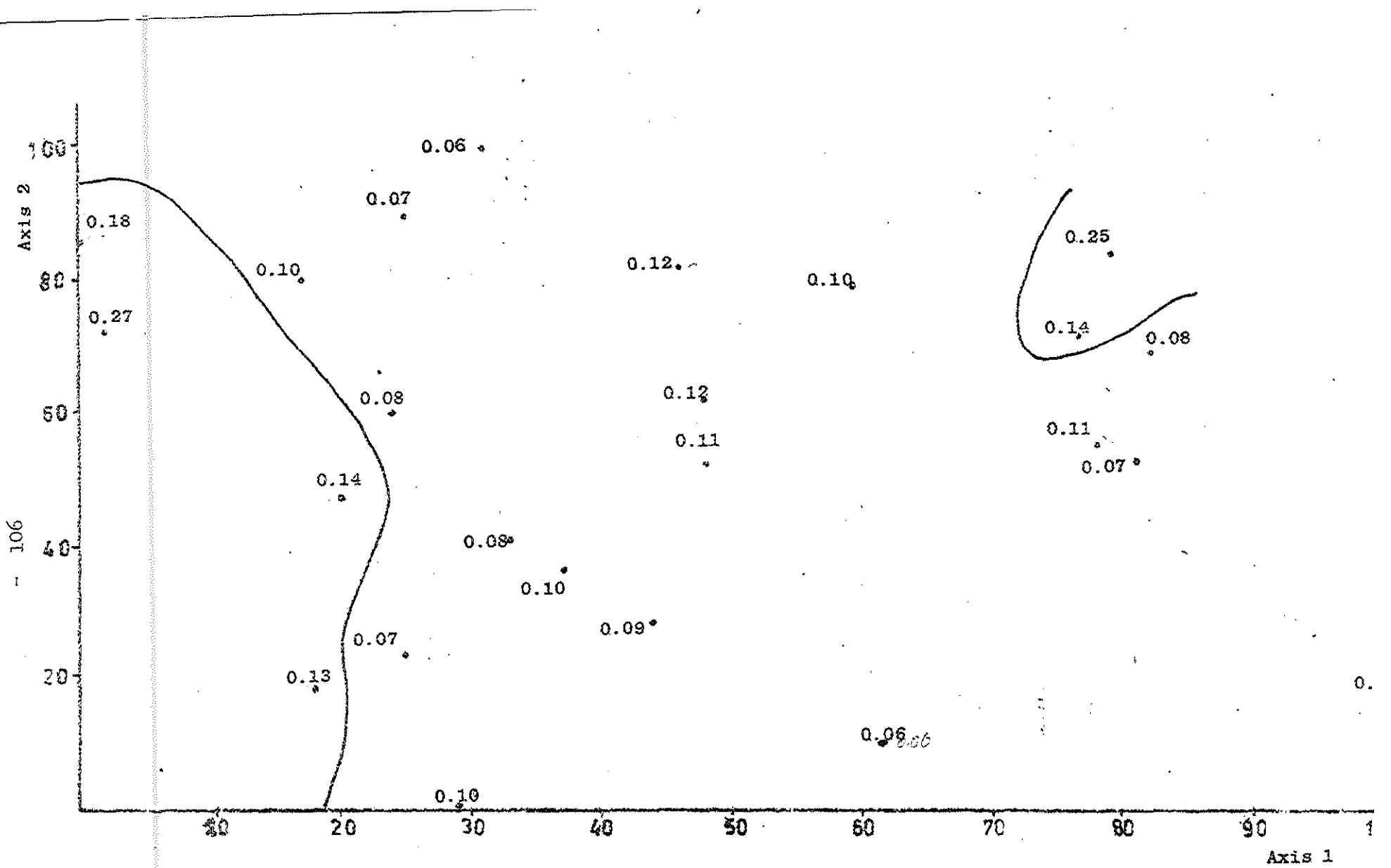


Fig. 27 Detrended correspondence analysis ordination diagram of group 3 stands with the values of K averaged over all the depth (meq/100g soil) superimposed

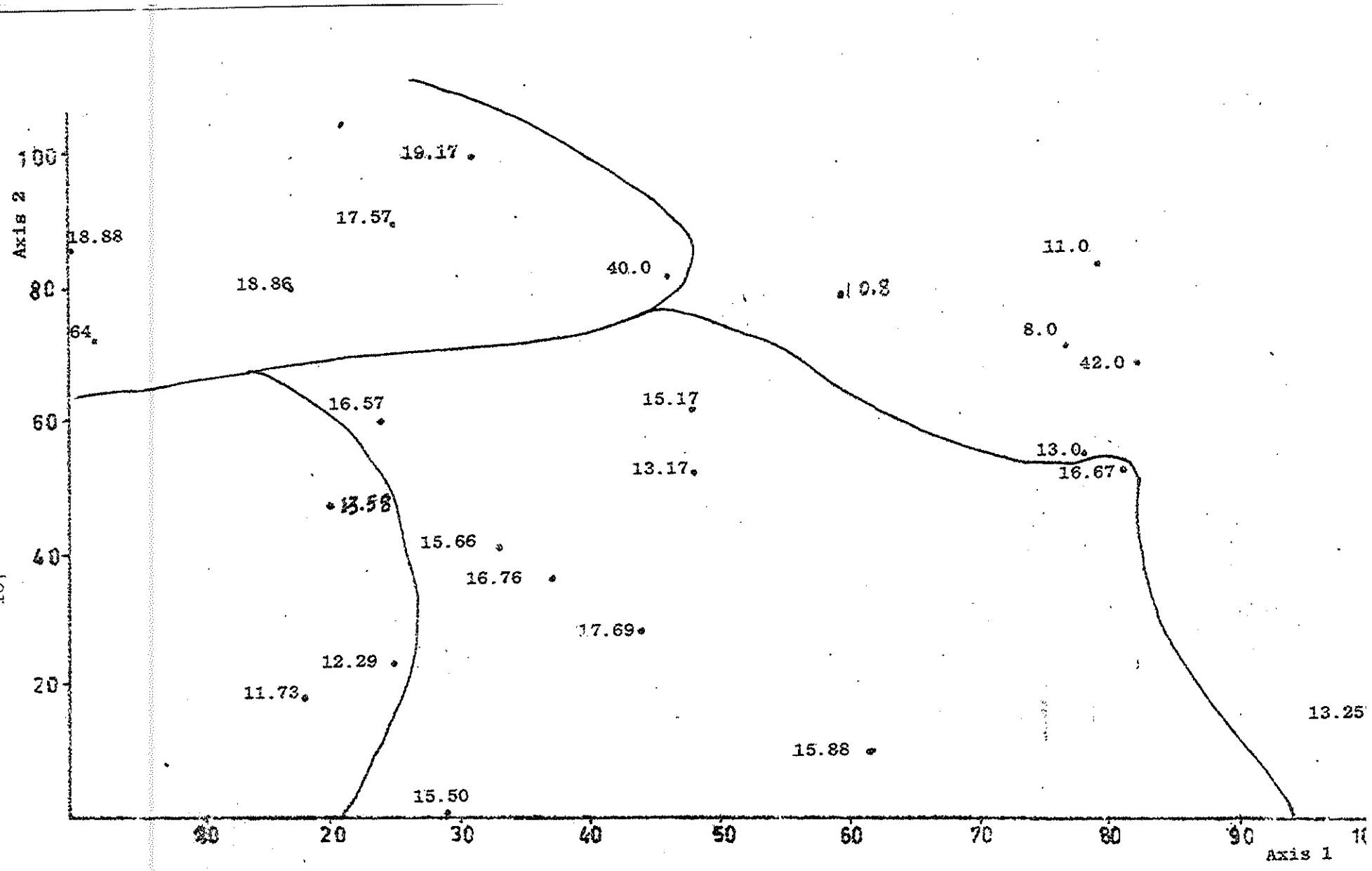


Fig. 28 Detrended correspondence analysis ordination diagram of group 3 stands with the values of Ca averaged over all the depth (meq/100g soil) superimposed

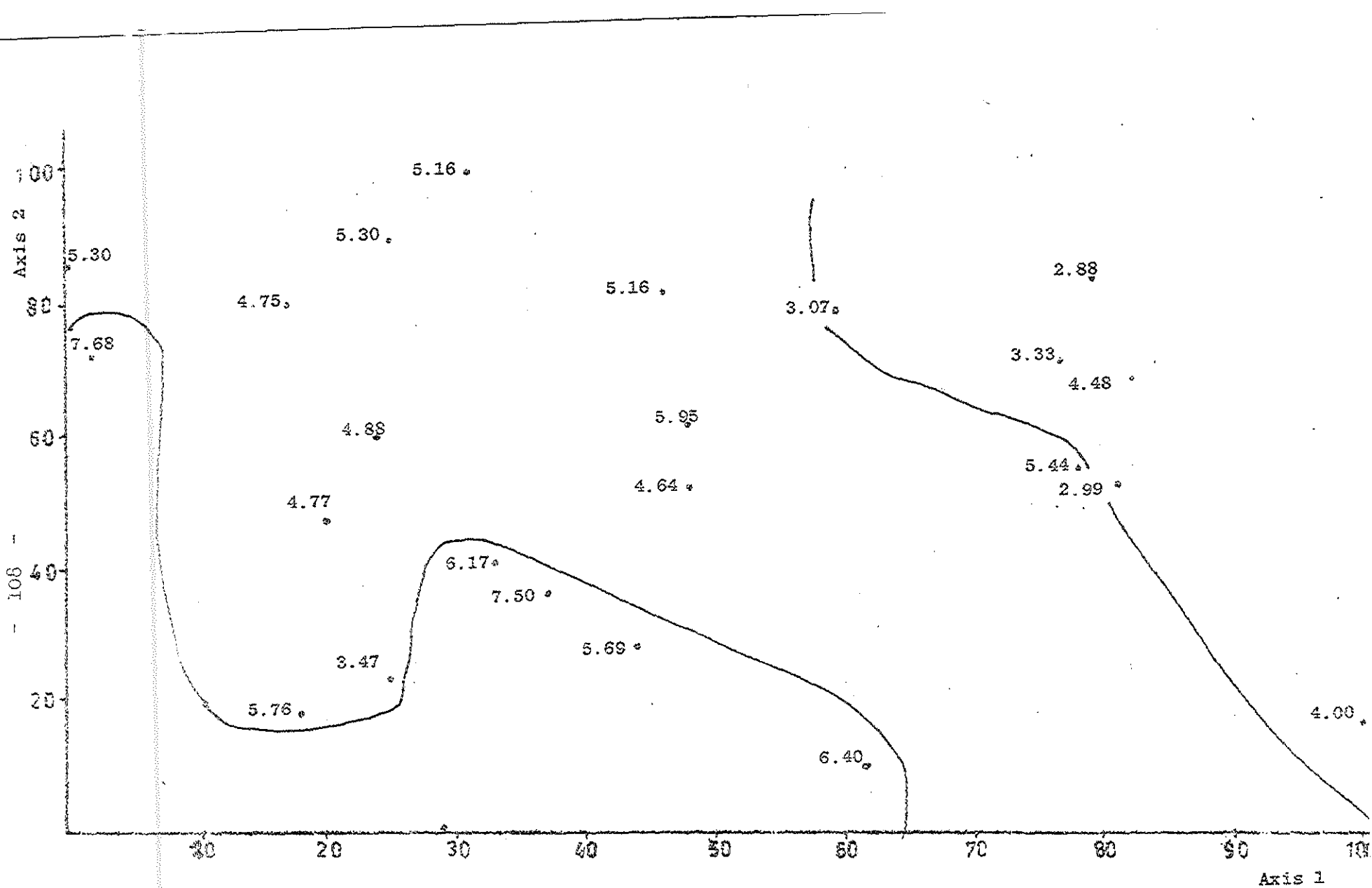


Fig. 24 Detrended correspondence analysis ordination diagram of group 3 stands with the values of Mg averaged over all the depth (meq/100g soil) superimposed

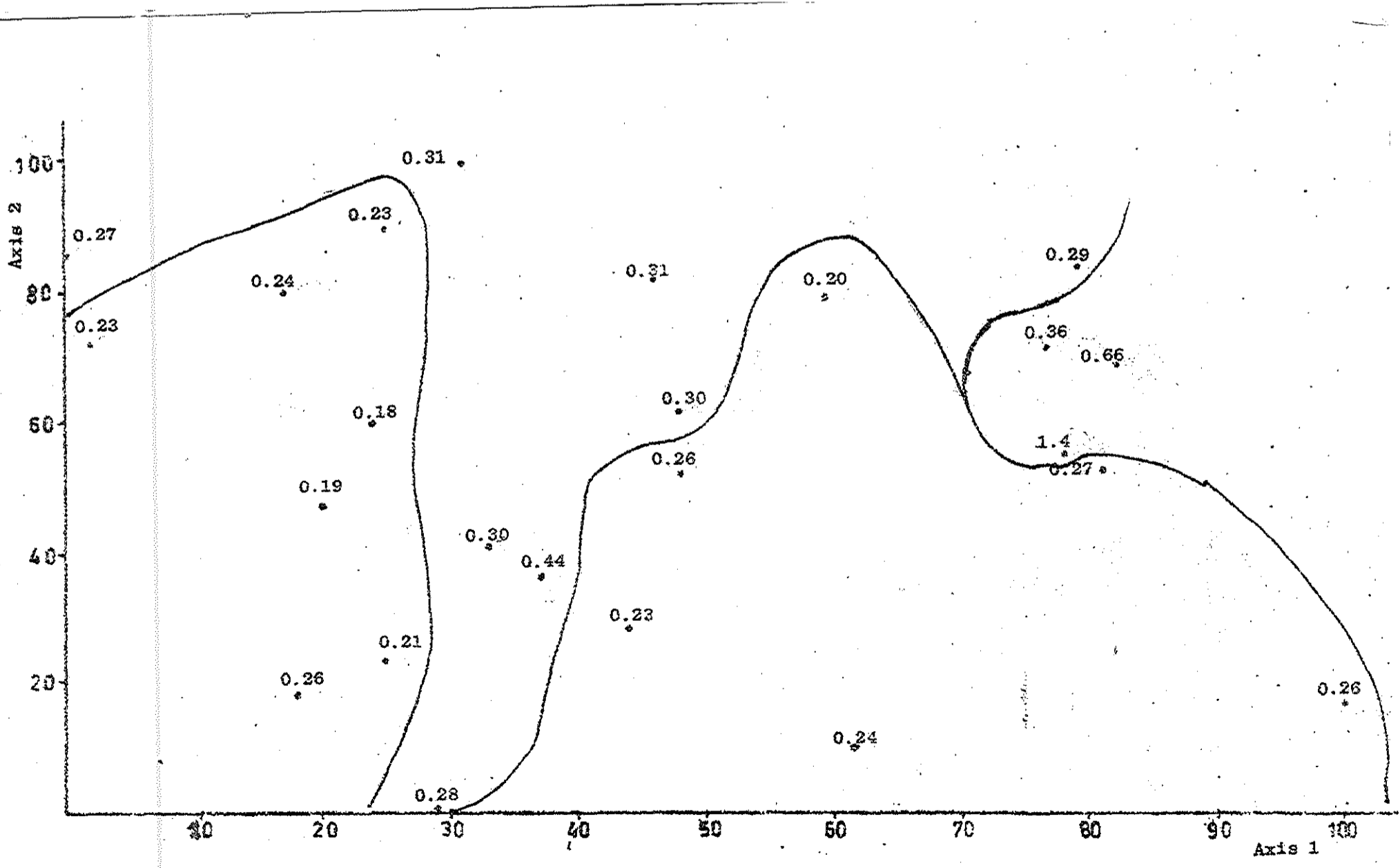


Fig. 30 Detrended correspondence analysis ordination diagram of group 3 stands with the values of Na averaged over all the depth (meq/100g soil) superimposed

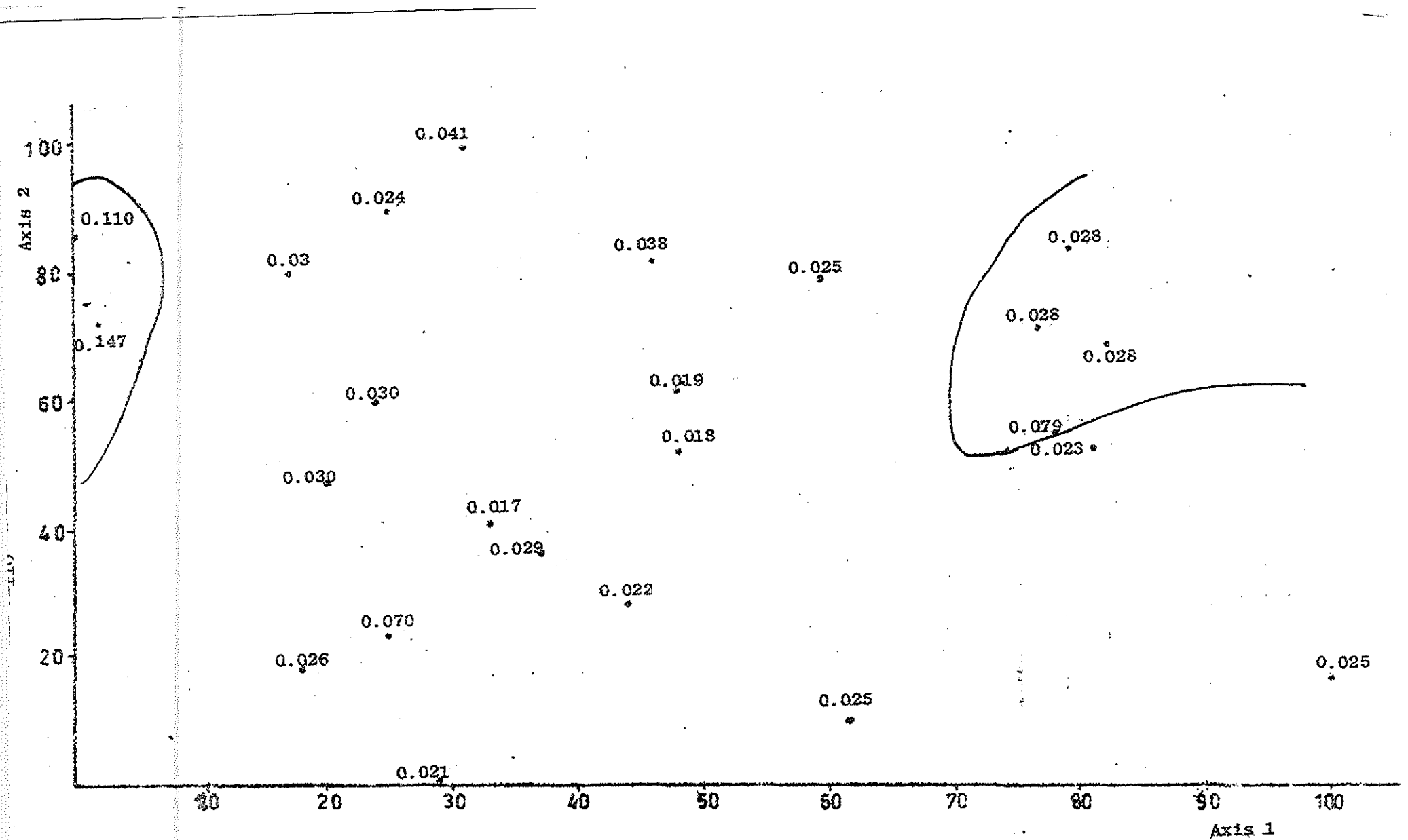


Fig. 31 Detrended correspondence analysis ordination diagram of group 3 stands with the values of Mn averaged over all the depth (meq/100g soil) superimposed

of the soils and also added the elements that were accumulated in the plant biomass to the ground. On the other hand, the higher calcium and potassium in the soils of the stands with high first axis ordination scores could be attributed to the higher clay and silt content of the soils of these stands which had increased their cation adsorbing capacity. The cations magnesium and manganese are also observed to be high on the stands with low ordination scores. As is indicated in the foregoing discussion, this could be attributed to higher organic matter content of the soils. The plants could be said to have actively accumulated these cations resulting in their release to the ground on death and decay. Moreover, the low pH created by high organic matter content of the soils could have increased the availability of the element manganese (Buckman and Brady, 1974).

The cation sodium showed a higher concentration in the stands with high first axis ordination scores. This was attributable to the high clay content and the arid conditions prevailing in these stands resulting in less loss through leaching and thus the accumulation of the cation in the soils.

As is indicated in Figure 32 detrended correspondence analysis-weighted average hybrid ordination also gave results that support the foregoing finding. Stands with low ordination in the first axis were characterized by high altitude, higher organic matter and higher amounts of magnesium and manganese and the stands with high first axis ordination scores were characterized by higher soil conductivity and higher sodium contents.

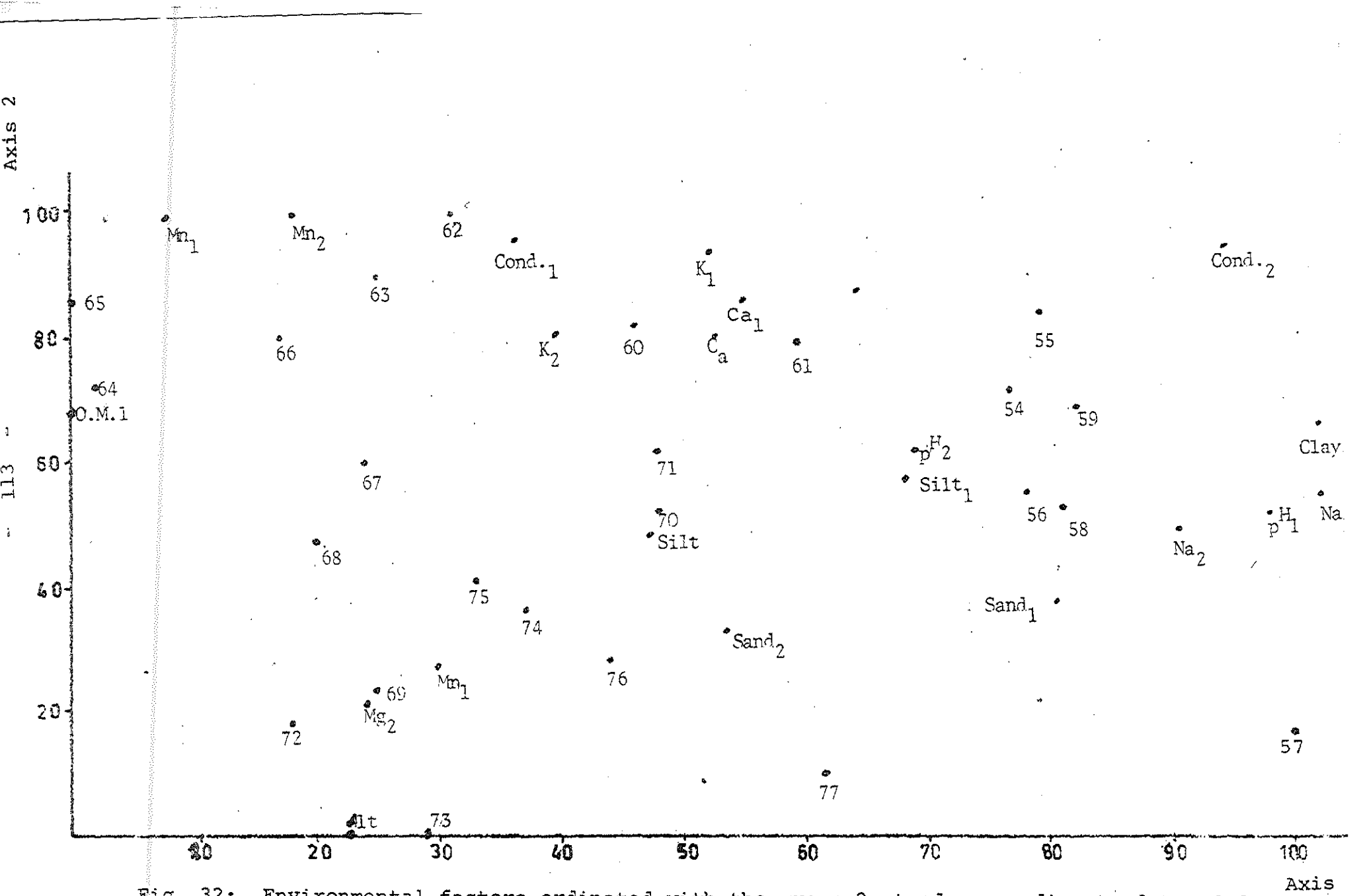


Fig. 32: Environmental factors ordinated with the group 2 stands according to detrended correspondence analysis weighted averages hybrid ordination.

CHAPTER 5

SOME RECOMMENDATIONS FOR THE MANAGEMENT OF THE VEGETATION  
ON THE EASTERN ESCARPMENT OF ERITREA

Vegetation has a key role in maintaining the productivity of the environment. It provides food for animals and a standing cover to protect the land from wind and water erosion. In arid lands the vegetation cover is fragile and the forces of erosion strong. In using aridlands, one has to recognize the limitations imposed by a harsh environment and manage them accordingly. Rainfall is not only low but also erratic falling in big showers in short periods interspersed with long dry periods. Plant growth, dependent on available soil moisture, is thus limited to short bursts separated by long periods of quiescence. Therefore, in arid land management plant material produced in short bursts must be conserved and its use spread over long dry non productive periods (Mensching and Ibrahim, 1977; Perry, 1981).

The vegetation on the Eastern Escarpment of Eritrea, which is predominantly under arid conditions, is grossly mismanaged. It has been subjected to intense and uninterrupted destruction exposing the surface to erosion, reducing future production and thus contributing to the desertification of the whole area.

Revegetation, primarily for protection, is then the issue of urgency in the area. The first question that has to be tackled on an ecological basis is the vegetation process. In order to do so the choice of species that could provide better and quicker protection and maintain high productivity is a prerequisite.

Ordination and classification studies on the vegetation of the region have indicated that the region can broadly be categorized into three groups depending on the amount and distribution of moisture.

Under category 1 fall the vegetation of the areas above 1400 meters altitude from sea level, which get their moisture from both the summer and winter rains but in small amounts. The region is observed to have very steep slopes, highly exposed soils and sparse vegetation. The area thus needs vegetation cover urgently to prevent it from further soil erosion. Terracing the land and planting it with shrubs and herbs would hold the soil and create conditions conducive for the regeneration of the natural vegetation. In support of this, inspite of the arid conditions and very steep slopes, the highest organic matter content of soils is observed, (in the areas that are terraced Agave sisalina and Opuntia ficus indica grows in abundance). Opuntia

ficus-indica has also economic value besides its protective function in that it provides edible fruits that are consumed in large quantities in the towns and villages in and around the escarpment. Nevertheless, the plant is observed to arrest the natural regeneration of the vegetation of the area and reduce species diversity. Other species that are preferential for the area, but presently with low seed numbers must thus be planted. For example, planting Dichrostachyus cinerea, Acacia etabica and Acacia senegal, would hold the soil well as well as enriching it because they are legumes and also give good yields of wood for fuel. Other economically valuable trees like Olea africana and Juniperos procera, which once were dominate species of the area, could also be tried. Exotic species that are drought tolerant, and able to grow fast in shallow soils could also be included in the list of species that could be used for re-vegetation of the area. For example Pinus halepensis, which is reported to be highly drought resistant, capable of growing in shallow eroded soils and also to give good timber yields in a relatively short period of time (Kapllar et. al., 1970; de Phillips, 1970) would serve well for this purpose.

In the second category is found the vegetation in the area between the altitude of about 1400 meters and 800 meters above sea level. This area gets substantial amounts of

winter rain and small amounts of moisture from the summer rains. On the whole, eventhough some years are much drier than others, moisture is not a limiting factor in this area. However, most of the natural vegetation cover has been removed through the intense devegetation that has been taking place.

Having higher moisture, less steep slopes and more plant cover, than the area under category 1, the soil conditions of the area under category 2 could have a better chance to improve and natural vegetation to regenerate quickly. Plants that are economically important but demand good soils conditions to establish could also grow better in this area than in the area under category 1 and thus should be tried.

In the third category is found the vegetation below the altitude of 800 meters above sea level, which gets its rain in <sup>the</sup> winter only. This area is highly arid and has relatively lower slope. Thus it is bound to have less loss of nutrients through leaching and erosion resulting in an accumulation of cations. For this reason, soils that approach saline and alkaline conditions prevail <sup>in the region.</sup> Moreover, as one goes away from the escarpment and approaches the sea, young soils with shallow depth, highly influenced by the parent material are observed. The effect of the sea in

increasing the salinity of the region also increases as one approaches the sea coast. The vegetation under category 3 is thus very fragile because of these highly unfavorable environmental conditions. Grazing and cutting plants for fuel or construction and expansion of field crops in the area must therefore be limited. Rather, measures of revegetation must be activated. In the process of revegetation, <sup>planting</sup> trees and shrubs around the drinking areas for livestock could reduce the effects of grazing. In the revegetation of the areas that have shallow soils with little transported materials and under the influence of the sea, plants that are highly tolerant to salinity, and that could establish themselves in shallow soils <sup>easily</sup> must be chosen. Around the base of the escarpment (e.g. Ailet plain) where the soils are predominantly transported from the massif, and where under ground water is relatively high, faster growing and economically important plants could be tried. Zizphys spina-  
christ, Balanities aegyptica and Acacia tortilis could serve for this purpose (c.f. Kaplan, 1970; Kual; 1970; Oedekoven; 1970).

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Appendix A: Vegetation data collected from the Eastern Escarpment  
of Eritrea

Field No.	Specimen No.	Scientific Name	Stands Number
1	1	<i>Ruellia patula</i> Jacq	24, 27, 28, 30, 33, 36, 39, 45
2	2	<i>Blepharis maderaspatensis</i> (L.) Ruth	9, 12, 39
3	3	<i>Justicia heterocarpa</i> T. Andres	14, 15, 16, 17
4	4	<i>Asystasia gangetica</i> (L.) T. Andres	36, 37
5	5	<i>Peristrophe bicalculata</i> (Vahl) Nees	5
6	6	<i>Nonechinia debele</i> (Forsk) Nees	60, 62, 66, 69, 70, 71, 73, 74, 75, 75,
7	7	<i>Ruellia prostrata</i> T. Andres	62, 63, 64, 65
8	13	<i>Ecbolium gymnostachyum</i> (Nees) Milne Redhead	10, 11, 14, 20
9	16	<i>Dyschoriste radicans</i> Nees	62, 72, 75, 76, 77
10	17	<i>Hypoestes verticillaris</i> (Linn, f.) Roem & Schult	60, 70, 76
11	18	<i>Barleria eranthemoides</i> P. Br	53
12	19	<i>Barleria prinites</i>	60, 65, 66, 67, 68, 69
13	20	<i>Justicia striata</i> (Kh.) Bullock	29, 32, 33, 34, 41, 44, 46, 49, 50, 54, 55, 56, 57, 58, 61, 63, 66, 67, 70, 71, 75, 77,
14	21		54, 67
15	22	<i>Blepharis maderaspatensis</i> (L.) Roth	61
16	23	<i>Justicia flava</i> Vahl	33, 36, 37, 38, 39, 41, 42, 43, 45, 47, 48, 52
17	24		28, 29, 32
18	25	<i>Justicia cordata</i> (Nees) T. Andres	64, 65, 66, 68, 74, 75, 76
19	26	<i>Thunbergia alta</i> Boj ex. sims	26, 27, 28, 29, 30, 32
20	28	<i>Corbrchonia decumbens</i> (Forsk.) Exell	9
21	29	<i>Zaleya pentandra</i> (L.) Jeffrey	4

Appendix A continued

<u>Field No.</u>	<u>Specimen No.</u>	<u>Scientific Name</u>	<u>Stands Number</u>
22	32	<i>Mallugo nudicaulis</i> Lam.	54
23	33	<i>Pupalia lapocea</i> (L.) Jues	9, 12, 20, 21, 22, 23, 24, 25, 27, 28, 29, 30, 31, 32, 33, 39, 48, 51
24	34	<i>Amaranthus graecizans</i> L.	1
25	35	<i>Digeria alternifolia</i> (L.) Aschera	1, 10, 11, 12, 13, 14, 15, 21, 22, 23, 24, 25, 26, 27 28, 29, 31, 32, 33, 39, 42
26	36	<i>Aerva lanata</i> (L.) Juss	55, 58, 61, 70
27	37	<i>Aerva perisca</i> (Burm.f) Meriill	7, 8, 19, 20, 21, 22, 23, 24, 31, 38, 48
28	38	<i>Achyranthus aspera</i> L.	1, 3, 6, 7
29	39	<i>Amaranthus hybridus</i> L.	12
30	40	<i>Rhus abyssinica</i> Oliv.	66
31	41	<i>Rhus natalensis</i> Kravs	54, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 74, 75
32	42	<i>Sauromatum</i> sp.	28, 29, 36, 37, 42, 46,
33 $\phi$	45	<i>Torilis arvensis</i> Huds. Link	34, 35, 38, 42, 43, 44, 45 46, 50, 52, 53
34	46	<i>Pimpinella</i> sp.	19, 27, 28, 31, 34, 35, 36, 37, 43, 53
35	47	<i>Acokanthera shimperi</i> (A.D.O.) Benth.	34, 35, 36, 37, 40, 41, 43, 44, 46, 53, 57, 58
36	48	<i>Carissa edulis</i> Vahl.	27, 31, 37, 54, 56, 57, 58, 60 61, 62, 63, 66, 67, 68, 69, 70 71, 72, 73, 74, 75, 76
37	49		2, 3, 4, 5, 6, 7, 8, 11, 12, 24

Appendix A continued

<u>Field No.</u>	<u>Specimen No.</u>	<u>Scientific Name</u>	<u>Stands Number</u>
38	51	<i>Pergularia daemia</i> (Forsk.) Chiou	1, 12, 13, 14, 15, 32, 33
39	52	<i>Huernia macrocarpa</i>	47
40	53	<i>Cynanchum tetrapetrum</i> (Turcz.) Dyer ex. Bullock 1956.	49
41	54	<i>Echidnopsis dammanniana</i> Spreng Ex. N.E.Br.	56, 57
42	57	<i>Veronia</i> sp.	30, 38, 43
43			40, 41, 42, 44, 45, 46, 52
			53, 54, 55, 56, 57
44	59	<i>Tridax procumbens</i> L.	9, 15, 18, 25, 26, 27, 28, 29
			31, 32, 41
45	62	<i>Galinsoga</i> sp.	37, 38, 39, 40, 42, 47
46	64	<i>Rhainvillea</i> sp.	28, 30, 33, 37, 43, 46
47	65	<i>Gnaphalium</i> sp.	14, 21, 26, 38, 42, 43, 45
			46, 47, 51, 52, 53
48	66	<i>Sonchus gigas</i> Boulos ex. Humbert	9, 10, 11, 13, 15, 16, 17, 18
			19, 20, 21, 22, 23, 24, 25,
			32, 33, 36, 38, 39, 40, 41,
			43, 45, 47, 51, 52,
49	67	<i>Sonchus</i> sp.	1, 6, 7
50	68	<i>Helichrysum glumaceum</i> D.C	49, 50, 51, 52, 57, 58, 59, 74
51	69	<i>Conyza pedunculata</i> Mill.	26, 27, 28, 29, 31, 32, 33, 34
			35, 36, 40
52	70	<i>Pulicaria shimperi</i> DC.	1, 2, 3, 6, 9, 11, 14
53	71	<i>Vernonia cinerea</i> (L.) Less	1
54	74	<i>Bidens pilosa</i> L.	16, 28, 29, 34, 35
55	75	<i>Crassocephalum</i> sp.	26, 27, 28, 29, 30, 33, 34
			35, 42, 44, 46, 51, 52, 53
56	76	<i>Bidens prestinariaeformis</i> (Votkva) Cuf	19, 20, 21, 24, 26, 29, 30
			31, 32, 33, 36, 37, 38, 39
			41, 42, 43, 44, 45, 46, 47, 52

Appendix A continued

<u>Field No.</u>	<u>Specimen No.</u>	<u>Scientific Name</u>	<u>Stands Number</u>
57	77	<i>Notonia coccinea</i> Oliv. and Hiern	54,63,64,66,67,72
58	80	<i>Psidia punctulata</i> D.C. Voltke	54,55,56,57,58,59,60,61 62,63,64,65,66,67,68,70 72,73,74,75,76,77
59	85	<i>Heliotropium longifolium</i> (A.D.C) Bunge	48,49,50,51
60	86	<i>Heliotropium subulatum</i> Dc.Markelli	55
61	87	<i>Heliotropium aegypticum</i> Lehm.	54,55,60,61,62,64,65,67 68,69,72,73,74
62	88	<i>Heliotropium albohispidum</i> Bok.	6,9
63	89	<i>Cyanoglossum</i> sp.	18,27,34,35,40,41
64	91	<i>Cardamine</i> sp.	34,47
65	92	<i>Parsetia</i> sp.	3,8
66	95	<i>Brassica</i> sp.	39,52
67	96	<i>Commiphora shimperi</i> (Berg.) Engl.	32,33
68	97	<i>Commiphora habessinica</i>	64,65
69	98	<i>Nahlenbergia</i> sp.	19,38
70	99	<i>Maerua</i> sp.	9,16,27
71	100	<i>Roscia</i> sp.	30,63
72.	105	<i>Cadaba farinosa</i> Forsk.	5
73	107	<i>Pollichia campestris</i> Ait.	65
74	108	<i>Silene</i> sp.	38,41,42,43,44,45,51,52
75	109	<i>Cerastium</i> sp.	46,47
76	110	<i>Arenaria serphyllifolia</i> L.	41,42,44,46,49,51
77	111	<i>Polycarphaea eriantha</i> A. Rich.	1
78	112	<i>Maytenus senegalenses</i> (Lam.) Excll	9,10,11,16,17,18,19,20 21,22,23,24,25,26,27,31 33,62,53
79	113	<i>Maytenus</i> sp.	54,56,58,64

Appendix A continued

<u>Field No.</u>	<u>Specimen No.</u>	<u>Scientific Name</u>	<u>Stands Number</u>
80	115	Suedia sp.	6,7
81	116	Chenopodium schraderianum Roem. et. Sch.	66
82	119	Combretum molle R.Br. ex. G.Don	19,26,27,29,30,31,33,34 35
83	121	Seddera sp.	4,6
84	122	Evolvulus alsinoides (L.) L.	1,9,10,13,15
85	123	Crossula alba	49
86	124	Crassula sp.	35,44,52
87	133	Cucumis dipsaceus Spach.	25
88	136	Ipomea sp.	14,15,16,17,18,20,21, 22,23,24,25,27,29,37,39 41,42,43,45,47,51
89	137	Phyllanthus sp.	22,23,39
90	138	Euphorbia tirucalli L.	56,64,65,69
91	140	Securineja virosa	20,22,26,27,28,29,30 31,32
92	141	Acalypha fruticosa Forsk.	18,19,20,23,27,28,29
93	142	Euphorbia hirta L.	13,15,17,18,20,21,24, 25,26,29,33,48
94	143	Acalypha endica L.	8
95	144	Phyllanthus sp.	12,13,16,17,18,19,20,21 24,25,26,27,28,29,30,31 32,33,36,37,38,39,40,42 45,47,52,53
96	146	Phyllanthus maderspatensis L.	59,61,65,71
97	147		9,13,16,28
98	148	Acalypha sp.	21,22,25,31
99	149	Euphorbia shimperi Prest.	28,29,34,38,40,42,44, 52,53

Appendix A continued

<u>No.</u>	<u>Specimen No.</u>	<u>Scientific Name</u>	<u>Stands Number</u>
100	150	Euphorbia sp.	4,5
101	151	Euphorbia sp.	3,11,13,14,23,25,29
102	152	Crotolaria ononoides Benth	18,19,20,21,22,23,24 27,28,29,30,31,32,33 36,37,41,43,45,46,47,50 62,63,65
103	153		
104	155	Crotolaria sp.	1,13
105	156	Crotolaria Chrysochlora Bank. f.	17,25,26,27,31,35,39 42,45,46,49,50,51,52,53
106	157	Trifolium campestre Schreb	35,40,41,42,43,46,47,52 53
107	158	Lotus lalambensis schw	15,25,49,51
108	159	Rhyncosia sp.	39,40,44,46,47,53
109	161	Acacia millifera (Vahl.) Benth.	5,11,13,14,15,16,17,18 19,20
110	162	Acacia ehernbergiana Hyne	3,4,6,7,8,10,11
111	163	Rhyncosia totta (Thun.) Dc.	55,62,63,66,67,72,74,76
112	164	Rhyncosia sp.	58,68
113	165	Rhyncosia sp.	62,63
114	167	Indigofera garckeana Voltke	62,65,66
115	168	Indigofera sessiliflora Dc.	49,50,51
116	171	Indigofera c.f. tanganfikensis Bak.f.	23,29,31,36
117	172	Indigofera bravicalyx Bek.f.	51,63
118	174	Indigofera sp.	73,74
119	176	Indigofera spinosa Forsk	54,55
120	177	Indigofera spiniflora Forsk	9,13,14,15,16,23,39,48
121	179	Tephrosia uniflora	27,37,47,57,77
122	180	Argyrolobium rupestre (E.Mey) wolp	49,51,52,62,67,68,69 70,72,74,76

Appendix A continued

<u>Field No.</u>	<u>Specimen No.</u>	<u>Scientific Name</u>	<u>Stands Number</u>
123	181	Indigofera sp.	3,4
124	182	Trifolium arvense L.	38,42,44,45,46,47,52,53
125	184	Indigofera sp.	
126	185		34,35,45
127	187	Indigofera hockesteri Bak.	55,57,58
128	188	Vicia sp.	53,58
129	189	Cassia obsus L.	40,41,42,43,45,49
130	191	Alysocarpus rugosus (Willd) Dc.	18,19,20,21,22,23,24,28 29,31,32,35
131	192	Cassia italica (Mill) F.W. Andr.	10,12,13,15,16,18,20,21 27,31,32,33
132	193	Cassia occidentalis L.	15
133	196	Dichrostachys cinerea L.	54,58,62,63,64,65
134	197	Acacia c.f. senegal (L.) Wild.	54,56
135	201	Indigofera trita l.f.	67
136	206	Acacia tortilis (Forsk.) Hayne	2,3,4,6,7,8,9,10,11,12 13,14,15,16,17,18,19,20 21,22,24,25,26,27,29,31 32,39,48,49
137	209	Crotolaria microcepa Carpa Benth.	9
138	210	Hypericum quartinianum A. Rich.	36
139	211	Geranium arabicum Forsk	27,40, 3
140	212	Pelargonium alchemilloides (L.)Ait	63,64,65,66,67,72
141	214	Ocimum sp.	14,15,18,22,23,24,26,31 32,38,41,42,47,50
142	215	Nepta sp.	63,72,73,75
143	216	Ocimum Saue Willd.	16,17,18,19,20,21,22 23,24,25,26,27,28,29,30 31,36,37,39,40,41,43,46 47,50,51,54,61,71,74

Appendix A continued

<u>Field No.</u>	<u>Specimen No.</u>	<u>Scientific Name</u>	<u>Stands Number</u>
144	217	Becium obvatum (E.Mey) N.E. Brown	55,56,57,58,60,61,62,70, 64,65,68,69,74,75,76,77
145	218	Leucas e.f. neuflizeana Cowb.	48,50,54,55,56,60,61,62 70,71,74,75,76,78
146	221	Leucas marticensis (Jacq.) Ait Fil	3,10,12,15,16,17,18,21 22,27,28,29,30,32,40,41 45,47
147	222	Leucas martinicensis (Jacq.) R. Br.	70,71
148	223	Satureja sp.	42,43,45
149	225	Hoslundia opposita Vahl	40
150	226		1,3,5,8,10
151	230		13,34,35
152	231	Ocimum sp.	31,32,33
153	232	Plectranthus sp.	41,42
154	233	Saturja biflora (ham.ex.Don) Brig. S.L.	29,40,51,53,56,66,67,72 74,76,77
155	234	Gyphia glandulifera Hochst ex. A. Rich.	37,43,44,46,52
156	235	Abysicarpus sp.	9,10,13,15
157	239	Hibiscus palmatus Forsk	48
158	240	Sida alba L.	28,30,32
159	244	Abutilon sp.	1,15
160	245	Pavonia arabica Hochst and Staud. ex. Boissler	8
161	246	Pavonia patens (Andr.) Chiov.	66
162	249	Hibiscus sp.	65,71
163	251	Hibiscus sp.	54,70,74
164	252	Sida ovata Forsk	56,60,62,71

<u>Field No.</u>	<u>Specimen No.</u>	<u>Scientific Name</u>	<u>Stands Number</u>
165	253		54,55
166	254		1,5,7,9,10,17,26,31,34 39,48
167	255	Hibiscus macronthus A. Rich	9,10,11,13,16,17,27,28,30
168	256	Hibiscus aponeurys Spague & Hetch	56,63,66,67,68,73,76
169	259	Myrsine africana L.	66
170	261	Chasmanthera sp.	18,21,28,29,30,32,37
171	262	Boerhavia c.f. repene L.	1,3,6,7,8
172	263	Commicarpus sp.	54,55,60,61,64,66,68,71 75
173	264		62,65
174	265		24,32
175	267	Jasminum floribundum R. Br.	60,62,63,64,66,67,68,71 72,73,74,75
176	268	Jasminum fluminense Vell.	62,63,64,65,66,72,74
177	269	Olea africana Mill.	54,56,58,62,63,64,66, 67,68,69,72,73,74,75
178	271	Oxalis oblongifolia stend. ex. Rich.	40,41,42,43,45,47,52,53
179	272	Oxalis corniculata L.	36,40,43,44,45,46,47,52 53,54,55,58,59,60,67,68 71,72,76
180	273	Plumbago zeylacia L.	23
181	274	Argemone mexicana L.	48
182	276	Polygala sphenopteta Fresen	67
183	277	Polygala persecariifolia Dc.	37,43,44,53
184	278	Polygala albida schinz	6,9,11,14,16,17,18,19,23 25,32,33,38,42,45,49,55
185	279	Polygala erioptera Dc.	54,56,57,28,66
186	281	Polygala abyssinica (R.Br.) Fresen	60,61,62,66,67,69,71,72, 76,77

Appendix A continued

<u>Field No.</u>	<u>Specimen No.</u>	<u>Scientific Name</u>	<u>Stands Number</u>
187	282	Oxygonum artiplicifolium (Meissn) Martell	14,29,54
188	286	Portulaca quadrifida L.	1,5,7,8,10
189	287	Portulaca oleraceae L.	7,8,11
190	289	Pavetta grandeniifolia Hochst. ex. Richard	27,28,34,36,37
191	290	Vangueria apiculata L. Schum	30,31,32,33,36,37
192	291	Catunaregam c.f. nilotica	22,27,28,29,30,31,33,40, 43
193	294	Kohautia caespitosa Schnizl	11,13,24,29,32,33,34,41 44,46,49,50
194	295	Kohautia coccinia Royle	7,8,9,11
195	296	Galium spurium L.	28,30,34,35,40,42,43,44 45,46,49,52
196	297	Spermacoce sp.	9,16,18
197	298	Canthium shimperianum A. Rich.	55,62,66
198	299	Spermacoce chaetocephala Dc.	13,15,16,17,18,19,20,21 22,23,24,25,26,27,29,31 32,33,35,37,38,42,43,44
199	300	Sageretia sp.	56,57,58,61,62,65,66,67 70,71,73,75,77
200	301	Teclea nobilis Delle	34,35,36,37,62,63,68
201	302	Dodonaea viscosa (L.) Tecq.	28,29,30,32,33,34,35,36 37,40,41,42,43,44,45,46, 47,48,49,50,51,52,53,54, 55,57,58,63,64,66,60,61 67,68,69,70,71,72,73,74 75,76
202	303	Osyris abyssinica Hochst. ex. Rich.	63,64,65,66,75

Appendix A continued

<u>No.</u>	<u>Speci- men No.</u>	<u>Scientific Name</u>	<u>Stands Number</u>
203	304	Lindenbergia sp.	18,21,24,28,32
204	305	Misopates orontium (L.) Rafi.	42,47,49
205	306	Croterostigma plantagineum Hochst	6
206	307	Anticharis linearis (Benth.) Aschers.	1,4,6,7,8,11,13,14,15,16 17,18,20,24,25,27,31,32, 33,34,35,36,37,38,41,42, 45,46,47,50
207	309	Asterolinum adoense Kunzl.	35
208	311	Solanum nigrum L.	16
209	313	Solanum indicum L.	7,8
210	315	Solanum incanum L.	21,22,23,24,25,27,28,29, 30,31
211	316	Nicandra physaloides (L.) Gaertn	15,20,21,24,25,29,30,39, 48
212	318	Melhania velutina Forsk.	66
213	319	Melhania steudneu Schwfth.	58,73
214	320	Triumfetta sp.	34,36,37
215	322	Triumfetta rhomboidaa Jacq.	18,19,20,21,23,25,26,27, 28,29,30,31,32,33,34
216	323	Grewia sp.	9,19,31,37,52
217	324	Corchorus sp.	15,16,19,24,34,40
218	325	Grewia c.f. mollis Juss	60,61,62,63,64,65,73
219	326	Grewia sp.	65,66,67
220	328	Grewia erythrae Schweinf.	54,57,60,61,62
221	330	Grewia villosa Willd.	18,19,26,32,37
222	334	Clerodendrum myricoides (Hochst) Votke.	63,66,72

<u>Field No.</u>	<u>Specimen No.</u>	<u>Scientific Name</u>	<u>Stands Number</u>
223	335	<i>Prema shimperi</i> Rngl.	14,15,16,17
224	336	<i>Cissus quadrangula</i> L.	64,65
225	337	<i>Cyphostemma cyphopetalum</i> (Fresen.) Desk	64,65,66,68
226	331	<i>Cyphostemma molle</i>	19,20,24,25,26,28,30,31 32,33,34,36,40,41,42,43, 45,46,47,57
227	339	<i>Fagonia bruquierei</i> Dc.	3,5,6,7,8,11
228	340	<i>Tribulus terrestris</i> L.	1,3,4,6,8,7
229	341	<i>Zygophyllum simplex</i> L.	1,2,3,4,5
230	342	<i>Mariscus macropus</i> C.B.Cl.	54,60,61,71,73,74,75,76
232	344	<i>Cyperaus rotundus</i> L.	3,5,8,14
233	345	<i>Mariscus</i> sp.	12,18,21
234	348	<i>Gladiolus</i> sp.	26,51,57
235	349	<i>Aneilima forskaoli</i> Kunth.	13
236	350	<i>Cammelina africana</i> L.S.	28,29,36,42,46,47
237	351	<i>Cammelina barbata</i> D. Don.	43,44
238	352	<i>Cammelina forskalaevi</i> Vahl.	2,4,7,8
239	352	<i>Cammelina diffusa</i> Burm F.	54,56,57,60,61,62,65,66, 67,70,71,72,73,74
240	354	<i>Cammelina albascens</i> Hassk.	9,10,12,13,15,16,18,19, 21,24,26,27,28,29,30,32 33,34,35,36,37,39,40,41 42,43,44,45,46,47,48,51
241	355	<i>Asparagus falcatus</i> L.	64,66,67,68,69,73,74,75 76
242	356	<i>Asparagus</i> sp.	62,63,
243	362	<i>Scilla</i> sp.	15,16,18,20,25,33,35,36 47
244	363	<i>Drimea</i> sp.	3,7,8
245	364		3,8
246	365	<i>Chenopodium</i> sp.	2,10

Appendix A continued

Field NSpeci-

<u>No.</u>	<u>men No.</u>	<u>Scientific Name</u>	<u>Stands Number</u>
247	366	<i>Pennisetum polystachyon</i> (L.) Schult.	62,64,67,68
248	367	<i>Tetrapogon cenchriformis</i> (Rich.) Pilg. ex. Clayton	1,2,3,5
249	368	<i>Digeria ternata</i> (Rich.) Stapf.	3,4,7,10,11,12,14,15,16 17,18,19,20,21,22,24,25 27,28,29,30,31,32,33
250	369	<i>Michrochloa Kunthii</i> Desv.	52,54
251			17,24,28,29,31,37,39,42, 44,46,48,50,51,53
252	372	<i>Eragrostis</i> sp.	5,8
253	373	<i>Dactyloctenium aegyptica</i> (Will.) De Lile	34
254	375	<i>Eragrostis aethiopica</i> chiov.	1,2,5,7
255	376	<i>Tetrapogon tenellus</i> (Roxb.) chiov.	3,4,5,6,7,10,11,13,14,20 21,22,24,27,28,29,31,33, 39,40
256	377		6,9,14,15,16,25
257	378	<i>Eleusine</i> sp.	3,4,8
278	381	<i>Acrachne</i> sp.	9,23
259	382	<i>Cenchrus setigerus</i> Vahl.	1,2,3,5,7,8,9,10,11,13,16 19,20,21,23,24,25,26,27, 28,29,39,49,51,52,
260	383		63,66
261	385	<i>Chloris pynothrix</i>	25,29,30,32,33,38,39,40, 42,44,46,47,48,52,53
262	386	<i>Chloris virgeta</i> Ewartz.	12,20,34
263	387	<i>Cenchrus ciliaris</i> L.	4,6,64,65,66

Appendix A continued

<u>Field No.</u>	<u>Specimen No.</u>	<u>Scientific Name</u>	<u>Stands Number</u>
264	388	Enneapogon cenchroides (Licht. ex. R.E. Sch.)	1
265	389		10,13,16
266	391	Eragrostis sp.	1,2,7,10,12,13,14,15,26 32,33
267	393	Eragrostis sp.	11,13,14,15,16,17,18,19 20,21,22,23,24,25,26,29, 30,31,32,33,35,39,40,41, 42,43,44,45,47,48,49,50 53
268	394	Eragrostis sp.	33,35
269	395	Aristida sp.	60,64,68,70,71,74,75,76 77
270	396	Aristida sp.	1,2,3,4,5,6,8
271	398	Arthroxon sp.	19,21,22,23,32,33,36,38, 41,43,46
272	400		10,11,12,13
273	401	Enneapogon shimperanum Hochst. ex. Richard	54,56,57,58,59,60,61,70, 76,77
274	402	Andropogon sp.	39,54,55,56,57,58,59
275	403	Harpachne shimperi Hochst ex. Richard	53,60,61,70,71,72,73
276	405	Optimenus sp.	45,46
277	406	Anthephora hochetettere Nees ex. Hoch.	74
278	407	Rhynchelytium repens (Willd.) Hubbaw	48,50,53,55,60,61,63,66 70,71,74,76
279	408	Bothriochloa radicans (Lehm.) Comus.	54,55,60,62,64,65,66,67, 68,69,70,71,72,73,74
280	409	Eragrostis sp.	54,55,57,58,59

Appendix A continued

<u>Field No.</u>	<u>Specimen No.</u>	<u>Scientific Name</u>	<u>Stands Number</u>
281	411	<i>Teropogon contortus</i> (L.) Beauv. ex. Roem. and Schult	54,55,56,57,58,60,61,62, 63,64,65,66,67,69,70,71 72,73,74,75,76
282	412	<i>Chloris amethystea</i>	55,63,66,68,69,70,71,74, 76
283	413	<i>Leptochloa</i> sp.	60,64,65,66
284	414	<i>Eragrostis</i> sp.	3,4
285	415	<i>Enneapogon cenchroides</i> (Licht. ex. R. and Sch.) Hubbaw	50,51,60,61,62,64,70,71
286	416	<i>Panicum coloratum</i> L.	26,27,28,31,40,45,52,53
287	417	<i>Enteropogon macrostachyus</i>	54,64,65
288	418	<i>Panicum maximum</i> Jacq.	54,62,64,67,70,71,73,74, 75
289	420	<i>Hyperthelia dissoluta</i> (Nees ex. Steudel) Clayton	62
290	421	<i>Themeda triandra</i> Forskal	66,67,69,72,73,74,75
291	422	<i>Setaria pallidifusca</i> (Schum.) stapf	26,27,28,29,30,31,32,33, 34,35,36,37,38,44,46,47
292	423	<i>Tetrapogon</i> sp.	48,59
293	424	<i>Tetrapogon</i> sp.	10,11,13,14,15,17
294	425	<i>Brachioria eruciformis</i> (Smith in Sibth and SM.) Grisenbach in Ledebour	26,28,29,30,31,32,35,36 37,38,40,41,42,43,44,45, 46,47
295	426	<i>Becheropsis</i> sp.	27,28,37,42,43,45
276	427	<i>Eriochlca nubica</i> (Steud.) Hachel and Stapf ex. Thell	20,27
297	428	<i>Brochiara deflexa</i> (Schum.) Hubbaw ex. Robyns	48,71
298	430	<i>Hyperrbenia filipendula</i>	54,55,56,57,58,59,60,61, 62,65,66,67,68,70,72,73, 74,75,76,77

Appendix A continued

<u>Field No.</u>	<u>Specimen No.</u>	<u>Scientific Name</u>	<u>Stands Number</u>
299	431	Tetrapogon cenchriformis	54,64,65
300	432		24,26,30,36,37,39,47
301	436	Terminalia brownii Fresen	18,19,20,21,22,26,27,28 29,30,31,33,34,36
302	437	Euclea shimperai (Dc.) Dandy	42,48,49,50,52,53,54,54 55,56,57,58,60,61,62,63, 64,65,66,67,68,69,70,71, 73,74,75,76,77
303	438	Punulum sp.	26,34,35
304			39,40,43,44,45,46,51,52,53
305			7, 8
306			12,22
307	443	Aloe sp.	54,55,56,57,60,61,62,63, 64,66,67,68,70,71,76
308	444	Optuntia ficus-indica (L.) Miller	62,63,64,65,66,70,71,74,
309	445	Acacia etbaica Schweinf	76,77
309	445	Acacia etbaica Schweinf	63,64,67,69,70,71,72,74, 75,76
310	284		55,56

Appendix B1

Altitude, Slope, Aspect and Percentage of Rock  
Cover of the Surface of the Stands from the  
Eastern Escapment of Eritrea

Stand No.	Altitude (meters)	Slope (deg.)	Aspect	% of Rockcover
1	190	0	0	0
2	190	0	0	0
3	190	14	S.E.	0
4	180	0	0	70
5	210	0	0	80
6	210	4.2	E	85
7	205	0	0	30
8	210	0	0	45
9	400	23	S	95
10	350	0	0	0
11	360	0	0	0
12	360	0	0	0
13	390	7	S	50
14	410	10	S	80
15	410	10	N	80
16	420	18	N.E.	70
17	430	5	S.E.	40
18	590	25	N.E.	80
19	600	29	N.E.	80
20	580	24	W	85
21	580	29	W	70
22	590	30	W	80
23	590	30	E	80
24	620	22	S	85
25	590	25	E	85
26	795	25	N.E.	60

Appendix B1 continued.

Stand No.	Altitude (Meters)	Slope (deg.)	Aspect	% of Rockcover
27	785	27	N.W.	60
28	790	27	N.W.	60
29	790	35	E	70
30	800	18	N	70
31	790	14	N	60
32	805	30	S.E	80
33	800	20	N.E.	40
34	990	22	N	30
35	1000	20	N	30
36	990	24	E	75
37	1000	24	E	75
38	1030	28	N.W.	30
39	1040	15	S.W.	80
40	1200	24	N.W.	30
41	1200	14	N.W.	30
42	1200	16	E	30
43	1200	25	N.W.	30
44	1205	22	N	30
45	1200	10	E	30
46	1210	15	E	30
47	1200	15	S.W.	25
48	1400	15	S.W.	75
49	1400	18	N	80
50	1390	30	W	75
51	1390	32	N.W.	20
52	1400	28	N.W.	20
53	1400	28	N.W.	20
54	1560	20	N	90
55	1580	19	N.E.	90
56	1600	8	N.W.	70

Appendix B1 continued.

Stand No.	Altitude (meters)	skope (deg.)	Aspect	% of Rockcover
57	1600	30	N.W.	70
58	1550	5	W	30
59	1550	12	W	60
60	1575	19	W	75
61	1560	9	W	40
62	1820	42	E	40
63	1760	45	E	35
64	1770	45	E	35
65	1790	45	E	45
66	1875	41	N	85
67	1800	41	W	85
68	1815	45	E	85
69	1770	39	N.E.	85
70	1975	24	S.W.	30
71	2045	24	S.W.	30
72	2045	24	N.E.	35
73	2035	35	N.E.	45
74	2075	35	N.E.	20
75	2050	23	N.E.	30
76	2015	25	S.W.	90
77	1995	25	S.W.	80

N = North

N.E = North East

E = East

S.E. = South East

S = South

S.W. = South West

W = West

N.W. = North West

Appendix B2: Percentage of sand of the soils from the  
Eastern Escarpment of Eritrea

Sand No.	Depth in cms.						
	10	20	30	40	50	60	70
1	81.4	78.4	71.4	70.76	83.40	R	R
2	71.04	78.04	70.04	87.04	83.3	87.04	R
3	71.04	71.04	77.04	71.04	75.04	65.04	69.04
4	63.04	64.04	59.04	R	R	R	R
5	73.04	73.04	77.04	71.04	75.04	75.04	71.04
6	65.04	73.04	R	R	R	R	R
7	73.04	79.04	79.04	85.04	81.04	83.04	69.04
8	59.04	R	R	R	R	R	R
9	79.04	R	R	R	R	R	R
10	55.04	49.04	48.04	47.04	41.04	39.04	55.04
11	40.76	58.96	41.76	48.76	41.76	55.76	59.76
12	83.4	85.4	87.4	R	R	R	R
13	71.4	71.4	71.4	71.4	R	R	R
14	81.04	R	R	R	R	R	R
15	83.04	77.04	79.04	R	R	R	R
16	78.32	80.68	76.68	85.68	78.32	80.68	R
17	74.32	72.32	R	R	R	R	R
18	78.32	76.32	74.32	82.32	79.40	80.40	R
19	71.40	75.40	69.40	R	R	R	R
20	69.40	65.40	R	R	R	R	R
21	77.04	68.04	73.04	R	R	R	R
22	71.04	77.04	73.04	R	R	R	R
23	76.04	71.04	75.40	69.40	75.40	83.40	80.40
24	75.04	75.04	67.04	75.04	70.68	R	R
25	77.04	75.04	77.04	79.04	R	R	R
26	81.04	81.04	81.04	79.04	83.04	83.04	82.68

Appendix B2 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
27	77.68	79.68	83.68	78.32	86.68	80.68	80.68
28	80.68	78.68	80.68	84.60	82.60	84.60	80.60
29	82.6	87.6	79.6	79.6	79.6	R	R
30	83.1	81.6	82.6	84.32	84.32	85.82	86.32
31	78.68	80.68	80.60=	81.10	81.60	81.60	77.96
32	81.96	83.96	83.96	83.96	83.96	83.96	85.96
33	75.96	77.96	79.04	87.04	79.96	82.96	R
34	75.04	82.04	81.04	85.04	82.96	82.96	85.96
35	82.46	81.40	82.90	76.04	76.76	78.76	83.76
36	79.76	80.76	80.76	81.76	83.76	81.04	80.04
37	81.04	84.54	81.04	81.04	80.68	85.18	82.68
38	70.68	68.68	69.68	R	R	R	R
39	71.04	R	R	R	R	R	R
40	79.04	76.04	79.32	70.32	66.32	74.32	70.32
41	80.32	81.32	88.32	84.32	85.04	86.68	84.68
42	78.68	77.32	82.68	84.32	84.32	85.76	86.76
43	73.76	78.76	75.04	79.76	75.04	76.98	75.04
44	80.26	83.84	87.04	87.04	83.04	85.04	87.04
45	79.04	83.04	83.04	89.04	81.04	79.04	84.04
46	81.4	81.4	85.9	81.4	84.4	79.4	85.4
47	81.4	90.4	88.4	85.3	85.4	R	R
48	90.4	90.4	89.48	86.4	84.04	R	R
49	81.96	86.40	90.76	88.40	91.76	92.76	93.76
50	90.76	94.76	91.76	89.90	91.40	87.26	90.26
51	84.90	81.40	81.04	81.04	91.04	89.54	91.04
52	77.04	89.90	89.90	91.04	93.04	R	R
53	76.68	80.68	86.68	86.68	85.68	88.68	89.68

Appendix B2 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
54	88.16	90.16	92.66	91.16	92.16	92.66	R
55	84.32	80.32	R	R	R	R	R
56	76.32	70.32	R	R	R	R	R
57	66.32	70.32	68.32	64.32	70.32	64.32	68.32
58	80.32	76.32	76.32	88.32	88.52	85.52	85.02
59	80.04	81.04	88.04	76.32	78.32	78.32	80.32
60	79.04	79.04	83.04	81.04	84.04	83.04	83.04
61	85.04	85.04	79.04	84.04	85.04	R	R
62	79.04	84.04	85.04	83.04	89.04	85.04	R
63	79.04	74.04	85.04	81.04	85.04	83.76	84.76
64	71.76	73.76	63.76	R	R	R	R
65	76.76	69.76	67.76	62.76	60.76	64.76	R
66	79.76	83.76	80.76	79.76	71.76	71.76	73.76
67	76.76	82.76	91.76	89.76	91.76	88.76	90.76
68	81.76	80.76	86.76	83.04	87.04	87.04	R
69	83.04	79.04	91.04	88.04	86.04	88.04	76.32
70	88.32	80.32	81.32	87.32	89.04	86.04	89.04
71	81.04	84.04	89.04	84.04	86.04	84.04	88.54
72	82.04	83.04	77.32	82.32	81.68	88.68	88.68
73	89.76	92.76	85.68	90.68	86.32	91.32	84.04
74	80.04	85.04	83.04	85.04	80.04	82.04	87.04
75	85.04	81.04	85.04	85.04	87.04	87.04	83.04
76	84.04	81.04	88.04	84.76	87.76	83.76	86.76
77	84.76	87.76	81.76	86.76	78.40	R	R

R = Bed rock reached

L = Sample lost

Appendix B3: Percentage of silt of the soils from the  
Eastern Escarpment of Eritrea

Stand No.	Depth in cms						
	10	20	30	40	50	60	70
1	13.64	15.64	21.64	10.28	10.64	R	R
2	21.00	15.00	20.64	8.64	8.82	10.86	
3	20.36	20.36	14.36	20.36	16.35	22.36	22.36
4	16.36	24.36	27.36	R	R	R	R
5	19.36	21.64	16.64	21.54	17.64	19.64	29.64
6	29.64	23.64	R	R	R	R	R
7	23.64	17.64	17.64	11.64	14.86	13.36	24.36
8	34.86	R	R	R	R	R	R
9	21.36	R	R	R	R	R	R
10	36.36	37.00	35.00	33.00	37.00	36.28	23.28
11	10.28	24.36	35.28	24.28	37.28	23.28	23.14
12	14.0	12.0	11.0	R	R	R	R
13	24	18	21	16	R	R	R
14	15.36	R	R	R	R	R	R
15	14.36	19.36	15.36	R	R	R	R
16	18.72	17.86	21.36	12.36	18.72	18.36	R
17	17.72	17.72	R	R	R	R	R
18	15.72	16.72	18.72	11.72	16.64	15.64	R
19	23.64	20.64	28.64	R	R	R	R
20	22.64	25.98	R	R	R	R	R
21	15.64	24.64	17.64	R	R	R	R
22	24.64	19.64	22.64	R	R	R	R
23	21.00	25.64	22.64	27.64	21.64	12.64	15.64
24	22.0	20.0	27.5	21.0	27.0	R	R
25	21.64	22.64	20.64	17.64	R	R	R
26	10.64	12.64	12.64	17.64	11.64	9.64	12.64
27	15.64	14.64	10.64	18.00	11.04	14.64	14.64

Appendix B3 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
28	13.68	15.68	13.68	9.23	11.36	9.86	12.36
29	13.36	9.36	17.36	16.36	16.36	R	R
30	8.86	10.36	9.36	10.36	12.36	11.36	10.86
31	14.00	12.00	13.08	11.58	12.08	12.08	17.00
32	12.36	12.36	12.36	12.36	13.36	12.36	11.36
33	14.36	14.36	13.64	9.00	17.36	13.36	R
34	17.0	9.14	11.64	10.14	9.72	12.72	11.72
35	10.22	14.92	12.42	18.64	17.92	16.92	12.92
36	12.92	11.92	14.28	14.28	13.28	16.64	17.5
37	11.64	7.14	12.64	14.64	15.00	11.50	13.00
38	23.0	25.0	R	R	R	R	R
39	18.64	R	R	R	R	R	R
40	16.64	15.64	15.36	22.72	24.36	15.36	16.72
41	12.72	15.72	9.36	12.36	11.64	10.5	12.5
42	15.00	16.36	12.36	12.36	12.36	12.42	9.92
43	16.92	10.92	16.00	11.28	18.00	18.14	16.00
44	12.78	14.0	10.0	10.0	13.0	11.0	10.0
45	14.86	12.5	12.5	10.0	13.86	17.5	14.0
46	10.28	12.64	9.14	14.64	12.64	17.64	11.64
47	13.64	6.64	9.64	10.82	10.64	R	R
48	7.64	7.14	8.64	11.14	13.5	R	R
49	15.36	10.64	7.28	9.14	6.92	5.42	4.28
50	5.92	4.28	6.64	8.14	7.14	10.78	7.78
51	10.78	13.64	14.00	14.00	6.00	8.50	7.0
52	16.00	6.14	7.50	6.0	4.5	R	R
53	17.0	12.5	10.0	10.0	12.0	9.0	8.0
54	7.0	5.0	2.5	4.0	4.0	1.5	R

Appendix B3 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
55	9.0	10.0	R	R	R	R	R
56	16.00	20.00	R	R	R	R	R
57	24.0	21.0	25.0	29.0	23.0	26.0	23.28
58	12.28	18.28	10.0	9.00	10.00	12.00	13.00
59	14.00	12.00	8.00	18.72	14.00	16.00	14.00
60	16.28	14.28	13.28	13.28	10.28	11.00	12.00
61	11.LL	10.00	14.00	10.00	8.00	R	R
62	16.00	13.00	11.00	13.00	9.00	11.00	R
63	16.72	22.72	13.72	16.72	13.72	15.00	14.00
64	21.00	18.28	15.28	R	R	R	R
65	16.28	22.28	23.28	28.28	28.23	25.28	R
66	15.28	11.78	14.28	14.28	19.28	21.28	19.28
67	20.28	13.28	7.28	8.28	6.28	10.28	7.88
68	13.28	13.28	10.28	12.00	10.00	10.00	R
69	14.00	15.00	7.00	10.00	12.00	10.00	18.72
70	9.72	14.72	7.72	10.72	9.50	12.00	9.50
71	10.00	13.00	8.00	12.00	11.00	12.00	9.5
72	14.00	12.00	15.72	11.72	13.36	9.36	9.36
73	8.28	6.28	12.36	8.00	12.36	7.36	14.00
74	16.00	13.00	14.00	13.00	17.00	16.00	12.00
75	13.5	16.0	13.00	13.00	11.00	11.00	15.00
76	12.00	15.00	10.00	12.28	9.28	13.28	9.28
77	11.28	8.28	16.28	11.78	18.04	R	R

R = Bed rock reached

L = Sample lost.

Appendix B4: Percentage of Clay of the soils from the Eastern Escarpment of Eritrea

Stand No.	Depth (cm)						
	10	20	30	40	50	60	70
1	4.96	5.96	6.96	8.96	5.96	R	R
2	7.96	6.96	9.32	4.32	2.88	2.1	R
3	8.6	8.6	8.6	8.6	8.6	12.6	8.6
4	10.6	11.6	13.6	R	R	R	R
5	7.6	5.32	6.32	7.32	7.32	9.32	9.32
6	5.32	3.32	R	R	R	R	R
7	3.32	3.32	3.32	3.32	4.10	3.60	6.60
8	6.1	R	R	R	R	R	R
9	3.6	R	R	R	R	R	R
10	8.6	13.96	16.96	19.96	21.96	13.96	20.90
11	18.96	16.68	22.96	26.96	20.96	20.96	17.10
12	2.6	2.6	1.6	R	R	R	R
13	4.6	4.6	7.6	6.6	R	R	R
14	3.6	R	R	R	R	R	R
15	2.6	3.6	5.6	R	R	R	R
16	2.96	1.46	1.96	1.96	2.96	0.96	R
17	7.96	9.96	R	R	R	R	R
18	5.96	6.96	6.96	5.96	3.96	3.96	R
19	4.96	3.96	1.96	R	R	R	R
20	7.96	9.32	R	R	R	R	R
21	7.32	7.32	9.32	R	R	R	R
22	4.32	3.32	4.32	R	R	R	R
23	2.93	2.96	1.96	2.96	3.96	3.96	R
24	2.96	4.96	5.96	3.96	2.32	R	R
25	1.32	2.32	2.32	3.32	R	R	R
26	8.32	6.32	6.32	3.32	5.32	4.68	4.68

Appendix B4 continued

Stand No.	Depth (cm)						
	10	20	30	40	50	60	70
27	6.68	5.68	5.68	3.68	1.68	4.68	4.68
28	5.68	5.68	6.68	6.04	6.04	5.54	7.04
29	4.04	3.04	3.04	4.04	4.04	R	R
30	8.04	8.04	8.04	5.32	3.32	2.82	2.82
31	6.32	7.32	6.32	7.32	6.32	6.32	5.04
32	5.68	3.68	3.68	3.68	2.68	3.68	2.68
33	9.68	7.68	7.32	3.96	2.68	3.68	R
34	7.96	7.82	7.32	4.82	4.32	4.32	2.32
35	7.32	3.68	5.32	5.32	4.32	3.32	R
36	7.32	7.32	4.96	3.96	2.96	2.32	2.46
37	7.32	8.32	6.32	4.32	4.32	3.32	4.32
38	6.32	6.32	7.32	R	R	R	R
39	10.32	R	R	R	R	R	R
40	6.32	8.32	5.32	6.96	9.32	10.32	12.96
41	6.96	2.96	2.32	3.32	3.32	2.82	2.83
42	6.32	6.32	5.32	3.32	3.32	1.82	3.32
43	9.32	10.32	8.96	8.96	6.96	4.88	8.96
44	6.96	2.96	2.96	2.96	3.96	3.96	2.96
45	6.1	4.46	4.46	0.96	5.10	3.46	1.60
46	8.32	5.96	4.96	3.96	2.96	2.96	2.96
47	4.96	2.96	1.96	3.88	3.96	R	R
48	1.96	2.46	1.88	2.46	2.46	R	R
49	2.68	2.96	1.96	2.46	1.32	1.82	1.96
50	3.32	0.96	1.96	1.96	1.46	1.96	1.96
51	4.32	4.96	4.96	4.96	2.96	1.96	1.96
52	6.96	3.96	2.96	2.96	2.46	R	R
53	6.32	6.82	3.32	3.32	2.32	2.32	2.32

Appendix B4 continued

Stand No.	Depth (cm)						
	10	20	30	40	50	60	70
54	4.84	4.84	4.84	4.84	3.84	5.84	R
55	6.68	9.68	R	R	R	R	R
56	7.68	9.68	R	R	R	R	R
57	9.68	8.68	6.68	7.68	6.68	9.68	8.40
58	4.40	5.40	3.68	2.68	1.48	2.48	1.98
59	5.96	6.96	3.96	4.96	7.68	5.68	5.68
60	4.68	6.68	3.68	5.68	5.68	5.96	4.96
61	3.96	4.96	6.96	5.96	6.96	R	R
62	4.96	2.96	3.96	3.96	1.96	3.96	R
63	4.24	3.24	1.24	2.24	1.24	1.24	1.24
64	7.24	7.96	10.96	R	R	R	R
65	6.96	7.76	8.96	8.96	10.96	9.96	R
66	4.96	4.46	4.96	5.96	8.96	6.96	6.96
67	2.96	3.96	0.96	1.96	1.96	0.96	1.96
68	4.96	5.96	2.96	4.96	3.96	2.96	R
69	2.96	5.96	1.96	1.96	1.96	1.96	4.96
70	1.96	4.96	0.96	1.96	1.46	1.96	1.46
71	2.96	2.96	2.96	3.96	2.96	3.96	1.96
72	3.96	4.96	6.96	5.96	4.96	1.96	1.96
73	1.96	0.96	1.96	1.32	2.32	1.32	1.96
74	3.96	1.96	2.96	1.96	2.96	1.96	0.96
75	1.46	2.96	1.96	1.96	1.96	1.96	1.96
76	3.96	3.96	1.96	2.96	2.96	2.96	3.96
77	3.96	1.96	1.96	1.56	2.96	R	R

Appendix B5: Color of the soils from the Eastern Escarpment  
of Eritrea (Hue(YR)  $\frac{\text{Value}}{\text{Chroma}}$ )

Stand No.	Depth (Cm)						
	10	20	30	40	50	60	70
1	10 5/4	10 5/4	10 5/4	10 5/4	10 5/4	R	R
2	10 5/4	10 5/4	10 6/4	10 6/4	10 5/4	10 6/4	R
3	10 6/2	10 5/2	10 5/3	10 5/3	10 5/3	10 5/3	10 5/3
4	10 6/3	10 6/3	10 6/3	R	R	R	R
5	10 4/4	10 4/4	10 4/6	10 4/6	10 4/6	10 4/6	10 4/6
6	5Y6/2	5Y7/ 1	R	R	R	R	R
7	10 5/4	10 5/4	10 5/4	10 5/4	10 5/6	10 5/6	10 4/4
8	10 5/4	R	R	R	R	R	R
9	10 5/4	R	R	R	R	R	R
10	10 4/3	10 5/6	10 5/6	10 5/6	10 5/6	10 5/4	10 5/4
11	10 4/3	10 6/2	10 6/2	10 6/2	10 6/2	10 6/2	10 6/2
12	10 5/6	10 5/6	10 5/6	R	R	R	R
13	7.5 5/6	7.5 5/4	7.5 4/6	7.5 4/6	R	R	R
14	10 4/3	R	R	R	R	R	R
15	10 5/4	10 5/6	10 5/6	R	R	R	R
16	10 5/4	10 5/4	10 6/6	10 6/6	10 6/6	10 6/6	2.5Y 6/4
17	2.5Y6/2	2.5Y6/2	R	R	R	R	R
18	10 4/4	10 5/4	10 6/4	10 7/4	10 7/4	10 7/4	R
19	10 5/6	10 7/8	10 8/6	R	R	R	R
20	10 6/2	2.5Y6/2	R	R	R	R	R
21	10 5/2	10 6/2	10 6/2	R	R	R	R
22	10 5/4	10 5/6	10 5/6	R	R	R	R
23	10 5/4	10 5/4	10 5/6	10 5/4	10 5/6	R	R
24	10 6/2	10 6/2	10 7/2	10 7/2	10 7/2	R	R
25	10 5/6	10 5/6	10 5/6	R	R	R	R

Appendix B5 continued

Stand No.	Depth (cm)						
	10	20	30	40	50	60	70
26	10 4/3	10 5/3	10 5/6	10 6/6	7.5 7/8	7.5 7/8	7.5 7/8
27	7.5 5/5	7.5 5/6	7.5 6/6	7.5 7/8	7.5 7/8	7.5 7/8	10 6/6
28	10 5/3	7.5 5/4	7.5 5/4	7.5 5/6	7.5 5/8	7.5 6/6	7.5 6/6
29	10 6/4	10 7/4	10 7/4	10 7/4	10 7/4	R	R
30	10 4/3	7.5 5/4	7.5 5/4	7.5 5/6	7.5 5/6	7.5 6/6	7.5 7/6
31.	10 4/3	7.5 5/4	7.5 5/6	7.5 5/6	7.5 5/6	7.5 5/8	7.5 6/6
32	10 5/2	10 5/3	7.5 5/6	7.5 5/6	7.5 5/6	7.5 5/8	10 7/6
33	10 4/3	10 5/3	7.5 5/6	7.5 6/6	7.5 6/6	7.5 7/8	-
34	10 5/2	10 5/4	10 5/6	10 6/4	10 6/4	10 6/6	10 6/6
35	10 5/3	10 7/3	10 7/3	10 7/4	10 7/4	2.5 7/4	2.5 7/4
36	10 5/4	10 5/6	10 6/4	10 6/6	10 7/4	10 7/4	10 7/4
37	7.5 5/7	7.5 5/6	10 6/4	10 6/6	10 7/4	10 7/4	10 7/4
38	10 6/3	10 6/3	10 6/3	R	R	R	R
39	10 4/4	R		R	R	R	R
40	7.5 4/4	7.5 4/4	10 6/4	10 5/4	10 5/4	10 5/4	10 5/4
41	7.5 5/4	7.5 5/4	10 5/6	10 6/4	10 6/6	10 6/6	10 6/6
42	7.5 4/4	7.5 4/4	10 6/4	10 5/4	10 5/4	10 5/4	10 6/4
43	7.5 3/3	5 3/4	7.5 4/4	7.5 5/4	7.5 5/4	10 6/6	10 6/6
44	7.5 4/4	7.5 4/4	10 4/6	10 5/6	10 5/8	10 5/8	10 5/8
45	7.5 4/4	7.5 5/4	7.5 5/6	10 5/6	10 5/8	10 5/8	10 6/8
46	7.5 4/4	7.5 5/4	7.5 5/6	10 5/6	10 5/8	10 6/6	10 6/6
47	7.5 4/4	7.5 5/4	7.5 5/6	10 5*6	R	R	R
48	10 5/4	10 6/4	10 6/4	10 6/4	10 6/4	R	R
49	10 5/6	10 5/8	10 6/4	10 6/6	10 6/6	10 6/6	10 6/6
50	10 5/6	10 5/8	10 6/4	10 6/6	10 6/6	10 6/6	10 6/6
51	10 4/6	10 5/4	10 5/4	10 5/4	10 5/4	10 6/6	10 6/6
52	10 3/3	10 4/4	10 5/3	10 6/6	10 6/4	R	R
53	10 3/3	10 3/4	10 4/3	10 6/3	10 6/4	10 6/6	10 6/6

Appendix B5 continued

Stand No.	Depth (cm)						
	10	20	30	40	50	60	70
54	7.5 4/4	7.5 4/4	7.5 5/6	7.5 5/6	7.5 5/6	7.5 5/6	R
55	7.5 4/4	5 4/3	R	R	R	R	R
56	10 6/4	10 6/6	R	R	R	R	R
57	10 5/8	10 5/8	10 6/8	10 6/8	10 6/8	10 6/8	10 6/8
58	10 5/3	L	L	L	L	10 6/4	10 6/4
59	10 5/3	10 5/4	10 5/4	10 6/4	10 6/4	10 6/4	10 6/4
60	10 5/3	10 4/3	10 4/3	10 5/3	10 5/3	10 6/3	R
61	10 4/3	10 4/3	10 3/3	10 3/3	10 3/3	R	R
62	10 4/6	10 4/6	10 5/4	10 5/3	10 6/6	10 6/6	10 6/6
63	10 4/2	10 4/4	10 5/4	10 5/4	10 6/6	10 6/6	10 6/6
64	7.5 3/2	7.5 3/2	7.5 3/2	R	R	R	R
65	7.5 3/2	7.5 3/2	10 4/3	10 4/3	10 4/3	10 4/3	-
66	10 4/2	10 3/3	10 4/3	L	10 4/4	10 5/6	10 5/6
67	10 4/3	10 4/3	10 4/3	10 5/3	10 6/4	10 6/4	10 6/4
68	10 4/3	10 3/3	10 4/3	10 4/3	10 4/3	10 4/4	R
69	7.5 4/4	7.5 4/6	7.5 4/6	10 5/4	10 5/6	10 5/6	10 5/6
70	10 5/4	10 5/4	10 6/4	L	L	L	L
71	10 5/6	10 5/4	10 4/4	10 5/6	10 6/4	L	10 5/8
72	10 5/2	10 5/2	10 4/4	10 5/6	10 5/6	10 5/2	10 6/4
73	10 5/4	10 6/4	10 6/4	10 6/4	10 6/4	10 6/4	10 6/4
74	10 5/4	10 5/6	10 5/6	10 6/4	10 6/6	10 6/6	10 6/6
75	10 5/4	10 5/6	10 5/6	10 6/4	10 6/4	10 6/6	10 7/4
76	10 4/4	10 5/6	10 6/6	10 6/4	10 6/4	10 7/4	10 7/4
77	10 5/6	10 6/4	10 6/6	10 6/6	10 7/6	L	R

N.B. R = Bed rock reached  
L = Sample lost

Appendix B6: pH of the soils from the Eastern Escarpment  
of Eritrea

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
1	7.9	8.2	8.3	8	7.6	R	R
2	7.4	7.1	7.5	7.4	7.8	7.9	-
3	7.8	7.0	7.2	7.4	7.2	7.3	7.2
4	8.7	7.7	7.6	R	R	R	R
5	8.4	8.3	R	R	R	R	R
6	8.4	8.3	R	R	R	R	R
7	8.2	7.8	7.5	7.4	4.4	7.5	7.5
8	7.6	R	R	R	R	R	R
9	7.5	R	R	R	R	R	R
10	7.9	8.1	8.2	7.6	7.5	7.8	7.9
11	7.6	7.5	7.8	8.1	7.7	R	7.8
12	8.0	8.2	8.5	R	R	R	R
13	7.6	7.8	7.8	7.7	R	R	R
14	7.0	R	R	R	R	R	R
15	7.0	7.5	7.6	R	R	R	R
16	7.8	8.1	7.7	7.7	7.7	R	R
17	7.8	7.8	R	R	R	R	R
18	7.1	7.2	7.7	7.0	7.3	7.1	R
19	6.5	7.0	6.9	R	R	R	R
20	7.6	7.3	-	R	R	R	R
21	7.1	6.9	6.5	R	R	R	R
22	7.0	7.3	7.3	R	R	R	R
23	7.2	7.4	7.2	7.3	7.3	7.4	7.3
24	8.3	8.4	8.5	8.2	8.5	R	R
25	8.3	8.2	7.7	7.6	R	R	R
26	7.0	6.9	7.2	7.0	6.8	6.8	6.8
27	6.7	7.1	7.1	6.8	6.9	6.9	6.9

Appendix B6 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
28	6.7	7.2	6.9	7.7	7.0	7.1	7.1
29	6.8	6.9	7.0	7.2	7.1	R	R
30	6.7	6.8	6.8	6.9	7.0	7.0	7.1
31	6.7	6.7	7.0	6.8	6.6	6.6	6.6
32	7.3	7.2	7.3	7.2	7.0	7.1	7.3
33	6.8	7.1	7.4	7.4	7.5	7.3	RR
34	6.7	6.8	6.8	6.8	6.6	7.0	7.0
35	6.5	6.6	6.5	6.4	6.1	6.1	6.4
36	6.2	6.5	6.3	6.3	6.4	6.4	6.5
37	7.4	7.4	7.4	7.3	7.3	7.3	7.3
38	7.6	7.5	7.8	7.7	R	R	R
39	7.8	R	R	R	R	R	R
40	7.5	7.2	7.5	7.0	6.8	7.1	7.2
41	7.2	7.2	7.3	7.3	7.3	7.3	7.3
42	7.0	7.2	7.2	7.2	7.2	7.3	7.2
43	7.0	7.1	7.2	7.2	7.1	7.2	-
44	6.9	7.0	7.3	7.2	7.1	7.2	7.2
45	7.0	7.2	7.1	7.0	7.0	7.1	7.1
46	6.5	6.9	7.4	7.4	7.4	7.4	7.5
47	7.0	7.5	8.4	7.9	7.6	R	R
48	7.7	7.7	7.9	8.0	7.9	R	R
49	7.7	7.9	7.8	7.9	7.8	7.6	R
50	7.7	7.8	7.6	7.9	8.1	8.4	8.3
51	8.0	8.2	8.1	8.2	8.2	8.1	8.1
52	7.1	7.6	7.7	7.9	7.9	R	R
53	7.2	7.3	7.2	7.6	7.6	7.6	R
54	6.6	6.8	6.7	6.5	6.5	6	R

Appendix B6 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
55	7.2	7.7	R	R	R	R	R
56	6.8	6.8	R	R	R	R	R
57	7.2	7	6.9	6.9	6.9	6.9	6.9
58	7.7	8.1	8.2	8.2	6.2	6.4	8.1
59	8.4	8	7.8	7.6	7.6	7.6	7.7
60	8.6	8.5	8.3	7.9	7.9	7.8	7.9
61	7.7	7.8	7.7	7.9	7.8	R	R
62	7.8	6.7	6.9	7.2	7.5	7.5	R
63	6.9	7.3	6.9	7.3	7.1	6.8	7.4
64	5.7	5.4	5.8	R	R	R	R
65	4.9	6.2	5.9	5.3	5.6	5.5	5.6
66	7.4	7.1	7.2	7.3	7.3	7.3	7.5
67	7.4	7.2	7.4	7.4	7.2	7.4	7.3
68	6.8	6.9	7.0	6.9	6.9	7.1	R
69	6.9	6.8	6.9	6.9	7.2	7.3	R
70	7.5	6.9	7.1	7.0	6.9	6.8	6.6
71	6.4	6.4	6.5	6.1	6.2	6.6	6.5
72	6.5	6.4	6.2	6.2	5.9	6.0	6.0
73	6.1	L	6.3	6.3	6.3	6.5	6.5
74	6.6	6.5	6.6	7.0	7.4	7.4	7.7
75	7.1	6.9	7.2	7.2	6.9	7.2	7.2
76	7.3	7.2	7.1	6.9	6.9	6.5	6.5
77	6.9	6.7	6.7	6.7	6.6	R	R

R = Bed rock reached

L = Sample lost

Appendix 7: Soil conductivity of the soils from the  
Eastern Escarpment of Eritrea (m mhos/cm)

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
1	0.144	0.165	0.150	R	R	R	R
2	3.101	4.135	6.201	4.134	0.775	1.085	R
3	0.930	1.809	4.134	3.101	3.101	1.137	3.101
4	0.18	0.956	2.119	R	R	R	R
5	0.245	1.292	2.429	3.101	2.532	2.067	2.016
6	0.724	0.724	R	R	R	R	R
7	0.310	0.853	1.318	1.240	1.860	1.318	2.326
8	0.310	R	R	R	R	R	R
9	0.594	R	R	R	R	R	R
10	0.0672	0.114	0.096	0.724	0.620	0.207	0.362
11	0.413	0.336	0.310	0.186	0.196	0.46	0.336
12	0.059	0.078	0.080	R	R	R	R
13	0.070	0.044	0.075	0.036	R	R	R
14	0.155	R	R	R	R	R	R
15	0.155	0.070	0.047	R	R	R	R
16	0.090	0.072	0.052	0.057	0.057	0.039	R
17	0.031	0.036	R	R	R	R	R
18	0.036	0.044	0.039	0.022	0.024	0.020	R
r 19	0.070	0.036	0.028	R	R	R	R
20	0.078	0.078	R	R	R	R	R
21	0.059	0.034	0.109	R	R	R	R
22	0.075	0.052	0.054	R	R	R	R
23	0.072	0.034	0.047	0.026	0.030	0.075	0.039
24	0.088	0.054	0.054	0.088	0.057	R	R
25	0.065	0.062	0.031	0.031	R	R	R
26	0.075	0.039	0.057	0.021	0.025	0.031	0.028
27	0.080	0.034	0.031	0.031	0.031	0.026	0.036

Appendix B7 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
28	0.052	0.080	0.052	0.072	0.039	0.036	0.034
29	0.059	0.039	0.031	0.031	R	R	R
30	0.054	0.052	0.041	0.036	0.026	0.028	0.034
31	0.033	0.019	0.019	0.024	0.024	0.019	0.024
32	0.036	0.028	0.034	0.036	0.034	0.041	0.041
33	0.062	0.026	0.028	0.023	0.020	0.020	R
34	0.052	0.024	0.031	0.026	0.018	0.031	0.031
35	0.020	0.016	0.015	0.014	0.015	0.015	0.011
36	0.039	0.041	0.017	0.016	0.013	0.015	0.020
37	0.052	0.031	0.026	0.031	0.028	0.028	0.028
38	0.018	0.020	0.026	0.057	R	R	R
39	0.11	R	R	R	R	R	R
40	0.039	0.026	0.039	0.044	0.0261	0.028	0.0411
41	0.034	0.034	0.026	0.025	0.031	0.028	0.026
42	0.052	0.028	0.028	0.026	0.026	0.026	0.026
43	0.023	0.023	0.026	0.026	0.031	0.023	R
44	0.031	0.024	0.025	0.024	0.025	0.023	0.026
45	0.041	0.026	0.026	0.031	0.024	0.041	0.028
46	0.083	0.044	0.031	0.023	0.026	0.024	0.028
47	0.096	0.041	0.026	0.025	0.036	O R	R
48	0.062	0.052	0.036	0.036	0.031	R	R
49	0.065	0.057	0.049	0.062	0.08	0.088	0.191
50	0.059	0.041	0.039	0.051	0.096	0.098	0.111
51	0.134	0.103	0.078	0.119	0.109	0.109	0.119
52	0.103	0.088	0.093	0.078	0.083	R	R
53	0.062	0.047	0.054	0.039	0.036	0.031	R
54	0.067	0.098	0.081	0.20	0.36	0.41	R

Appendix B7 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
55	0.082	0.017	R	R	R	R	R
56	0.124	0.124	R	R	R	R	R
57	0.103	0.248	0.186	0.196	0.191	0.238	0.362
58	0.310	0.310	0.982	0.930	0.724	0.419	0.121
59	0.114	0.465	1.80	1.76	2.12	2.38	1.99
60	0.116	0.129	0.76	0.310	0.646	0.853	1.085
61	0.067	0.067	0.088	0.057	0.059	R	R
62	0.096	0.101	0.191	0.140	0.075	0.106	R
63	0.054	0.039	0.031	0.034	0.034	0.036	0.054
64	0.745	0.12	0.54	R	R	R	R
65	0.124	0.196	0.171	0.083	0.075	0.093	0.065
66	0.217	0.114	0.116	0.109	0.072	0.059	0.078
67	0.723	0.646	0.613	0.513	0.562	0.386	0.284
68	0.049	0.049	0.049	0.052	0.052	0.09	R
69	0.44	0.049	0.054	0.036	0.034	0.028	0.047
70	0.72	0.052	0.088	0.062	0.054	0.065	R
71	0.88	0.088	0.083	0.067	0.090	0.109	0.083
72	0.62	0.054	0.052	0.059	0.070	R	R
73	0.052	0.034	0.036	0.021	0.041	0.052	0.062
74	0.044	0.025	0.026	0.034	0.024	0.024	0.025
75	0.039	0.028	0.018	0.011	0.011	0.019	0.031
76	0.026	0.036	0.033	0.036	0.026	R	R
77							

R = Bed rock reached

L = Sample cost

Appendix B8: Percentage of organic matter in the soils  
from the Estern Escarpment of Eritrea

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
1	0.68	0.57	0.50	0.47	0.43	R	R
2	0.82	0.55	0.40	0.29	0.70	0.17	R
3	0.49	0.42	0.24	0.26	0.26	0.26	0.12
4	0.42	0.38	0.33	R	R	R	R
5	0.59	0.42	0.26	0.26	0.16	0.16	0.24
6	0.59	0.24	R	R	R	R	R
7	0.40	0.26	0.19	0.19	0.12	0.09	0.29
8	2.13	R	R	R	R	R	R
9	1.54	R	R	R	R	R	R
10	0.89	0.79	0.58	0.49	0.49	0.38	0.33
11	2.10	1.80	0.82	0.25	0.20	0.35	0.33
12	0.99	0.84	0.33	R	R	R	R
13	0.41	0.51	0.33	0.30	R	R	R
14	1.15	R	R	R	R	R	R
15	2.02	1.14	0.82	R	R	R	R
16	0.79	0.30	0.35	0.33	0.48	0.33	R
17	0.82	0.69	R	R	R	R	R
18	1.48	0.79	0.54	0.24	0.27	0.22	R
19	0.97	0.39	0.24	R	R	R	R
20	2.02	1.10	R	R	R	R	R
21	1.43	0.97	0.87	R	R	R	R
22	0.93	0.44	0.41	R	R	R	R
23	1.93	1.02	0.25	0.26	0.29	0.35	0.21
24	1.21	0.82	0.75	0.47	0.40	R	R
25	0.77	0.54	0.49	0.63	R	R	R
26	2.19	0.78	0.95	0.22	0.27	0.41	0.31

Appendix B8 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
27	1.21	0.38	0.21	0.21	0.16	0.10	0.07
28	1.43	1.59	1.04	0.62	0.38	0.36	0.36
29	0.88	0.45	0.35	0.29	0.35	R	R
30	1.54	1.19	0.78	0.52	0.26	0.47	0.09
31	1.12	0.60	0.57	0.55	0.43	0.40	0.28
32	1.86	0.93	0.64	0.64	0.28	0.26	0.21
33	1.62	0.71	0.43	0.14	0.16	0.12	R
34	1.62	1.04	0.77	0.35	0.35	0.21	0.10
35	1.54	0.40	0.36	0.38	0.33	0.19	0.12
36	1.35	0.78	0.62	0.38	0.26	0.19	0.14
37	1.74	1.09	0.89	0.44	0.19	0.27	0.32
38	2.08	1.64	1.61	R	R	R	R
39	6.67	R	R	R	R	R	R
40	2.82	2.44	1.33	1.52	1.78	1.69	1.50
41	1.55	1.02	6.56	0.51	0.59	0.25	0.46
42	1.41	1.14	0.71	0.60	0.55	0.54	0.43
43	2.18	1.45	1.45	1.21	0.75	0.38	0.36
44	2.17	1.38	0.75	0.55	0.50	0.55	0.48
45	2.32	1.67	1.16	0.91	0.77	0.44	0.35
46	2.81	1.98	1.24	0.65	0.50	0.37	0.30
47	2.87	1.68	0.92	0.83	0.97	R	R
48	1.28	1.10	0.58	0.60	0.58	R	R
49	2.24	1.49	0.79	0.79	0.74	0.60	0.58
50	1.68	1.21	0.89	0.77	0.60	0.44	0.46
51	1.96	1.68	1.58	1.12	1.10	1.10	0.53
52	7.38	2.29	1.30	1.00	0.86	R	R
53	7.14	3.19	2.12	0.89	0.48	0.29	0.44

Appendix B8 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
54	1.85	1.12	0.59	0.68	0.59	0.55	R
55	1.62	1.59	R	R	R	R	R
56	1.88	0.80	R	R	R	R	R
57	2.46	2.07	0.56	0.41	0.37	0.38	0.49
58	2.56	2.72	2.14	2.37	1.37	1.73	0.58
59	1.46	1.10	1.50	1.31	1.18	0.92	1.06
60	1.81	2.02	1.67	1.73	1.22	0.98	0.82
61	2.54	1.83	1.38	1.79	2.21	R	R
62	2.49	1.39	1.49	0.82	0.61	0.70	R
63	3.1	1.91	1.03	0.74	0.60	0.07	0.21
64	5.73	5.67	4.25	R	R	R	R
65	8.2	5.11	3.33	3.33	3.79	2.36	R
66	6.42	5.60	5.23	3.16	3.47	1.47	2.04
67	4.99	2.97	2.15	1.49	0.97	0.63	0.53
68	5.29	4.91	L	3.03	L	2.56	R
69	6.52	2.97	1.79	1.96	0.72	0.64	0.67
70	3.07	2.73	0.95	0.78	0.74	0.43	0.36
71	1.79	1.79	1.79	0.86	0.61	0.53	0.53
72	3.80	4.28	3.73	1.93	1.54	1.50	0.95
73	3.07	0.58	0.56	0.16	0.44	0.47	L
74	2.07	1.16	1.35	0.47	0.74	0.47	0.30
75	1.72	1.34	1.00	0.82	0.79	0.67	0.49
76	3.92	1.63	0.82	0.72	0.61	0.33	0.35
77	2.45	1.26	1.14	1.17	0.82	R	R

R = Bed rock reached

L = Sample lost

Appendix B9: Potassium content of soils from Eastern  
Escarpment of Eritrea (meq/100 gm soil)

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
1	1.13	1.52	2.36	2.78	3.29	R	R
2	2.91	3.67	3.34	4.00	2.33	2.50	R
3	0.8	0.33	0.17	0.17	0.33	0.40	0.40
4	1.82	1.18	0.68	R	R	R	R
5	1.02	0.76	0.88	0.80	0.80	0.83	0.92
6	0.60	0.36	R	R	R	R	R
7	0.73	0.47	0.52	0.44	0.52	0.40	0.24
8	0.78	R	R	R	R	R	R
9	0.22	R	R	R	R	R	R
10	1.42	1.65	1.82	1.60	1.60	2.2	1.32
11	1.4	1.2	1.50	1.50	1.17	1.17	1.14
12	0.65	0.51	0.31	R	R	R	R
13	0.29	0.20	0.20	0.20	R	R	R
14	0.45	R	R	R	R	R	R
15	0.20	0.11	0.13	R	R	R	R
16	0.18	0.11	0.09	0.13	0.09	0.14	R
17	0.49	0.24	R	R	R	R	R
18	0.42	0.27	0.20	0.18	0.20	0.16	R
19	0.13	0.09	0.07	R	R	R	R
20	0.14	0.10	R	R	R	R	R
21	0.22	0.16	0.16	R	R	R	R
22	0.07	0.09	0.13	R	R	R	R
23	0.6	0.11	0.07	0.09	0.11	0.13	0.13
24	0.09	0.11	0.13	0.07	0.07	R	R
25	0.09	0.07	0.07	0.09	R	R	R
26	0.24	0.13	0.11	0.09	0.11	0.07	0.09

Appendix B9 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
27	0.20	0.09	0.07	0.11	0.09	0.09	0.09
28	0.24	0.18	0.16	0.13	0.11	0.11	0.13
29	0.13	0.11	0.09	0.09	0.11	R	R
30	0.31	0.22	0.22	0.13	0.11	0.11	0.09
31	0.29	0.18	0.16	0.16	0.16	0.16	0.11
32	0.31	0 -2	0.13	0.13	0.11	0.11	0.11
33	0.27	0.16	0.18	0.09	0.11	0.09	R
34	0.16	0.13	0.09	0.11	0.11	0.11	0.09
35	0.13	0.16	0.11	0.09	0.13	0.11	0.13
36	0.22	0.07	0.13	0.09	0.09	0.09	0.07
37	0.18	0.11	0.11	0.09	0.09	0.11	0.09
38	0.11	0.07	0.09	R	R	R	R
39	0.31	R	R	R	R	R	R
40	0.16	0. 8	0.11	0.09	0.09	0.07	0.09
41	0.09	0.04	0.02	0.02	0.04	0.02	0.04
42	0.11	0.02	0.02	0.02	0.02	0.02	0.02
43	0.11	0.07	0.07	0.04	0.04	0.04	0.04
44	0.11	0.07	0.04	0.04	0.04	0.02	0.04
45	0.11	0.09	0.04	0.04	0.04	0.04	0.02
46	.16	0.09	0.09	0.04	0.04	0.02	0.07
47	0.18	0.07	0.04	0.04	0.04	R	R
48	0.09	0.07	0.04	0.04	0.04	0.04	0.04
49	0.10	0.07	0.04	0.04	0.04	0.04	0.04
50	0.11	0.04	0.04	0.04	0.04	0.04	0.04
51	0.07	0.09	0.07	0.07	0.06	0.04	0.04
52	0.19	0.09	0.06	0.06	0.04	R	R
53	0.19	0.11	0.06	0.06	0.04	0.07	0.04

Appendix B9 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
54	0.20	0.12	0.14	0.14	0.10	R	R
55	0.32	0.17	R	R	R	R	R
56	0.14	0.08	R	R	R	R	R
57	0.12	0.10	0.08	0.06	L	L	L
58	0.08	L	L	L	L	0.06	0.06
59	0.10	0.08	0.08	0.08	0.12	0.07	0.06
60	0.12	0.10	0.60	0.09	0.10	0.08	L
61	0.12	0.12	0.10	0.08	0.08	R	L
62	0.10	0.08	0.06	0.06	0.04	0.04	R
63	0.14	0.08	0.06	0.06	0.04	0.04	0.04
64	0.32	0.28	0.22	R	R	R	R
65	0.24	0.18	0.18	0.18	0.16	0.12	R
66	0.16	0.12	0.12	0.08	0.08	0.08	0.08
67	0.16	0.2	0.07	0.06	0.06	0.04	0.06
68	0.18	0.18	0.14	0.12	0.12	0.08	R
69	0.12	0.08	0.08	0.08	0.04	0.04	0.06
70	0.13	0.11	0.11	0.11	0.11	0.07	0.11
71	0.13	0.13	0.11	0.11	0.11	L	0.11
72	0.18	0.13	0.13	0.11	0.11	0.11	0.11
73	0.11	L	0.09	0.09	0.13	0.09	R
74	0.13	0.13	0.09	0.09	0.07	0.07	0.09
75	0.09	0.07	0.07	0.09	0.07	0.09	0.07
76	0.13	0.11	0.04	0.04	0.07	0.07	0.09
77	0.09	0.09	0.07	0.07	0.07	L	R

R = Bed rock reached

L = Sample lost

Appendix 10 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
28	8.5	9.5	1.5	13.0	11.0	8.8	9.3
29	9.0	9.5	9.3	9.5	11.8	R	R
30	7.0	10.0	8.5	8.0	7.0	6.0	6.3
31	10.0	8.0	10.0	12.5	9.0	12.8	9.3
32	8.8	6.5	7.0	6.3	5.0	5.0	5.5
33	10.0	10.5	20.0	8.5	7.5	7.5	R
34	10.0	14.0	10.0	9.0	9.0	8.8	8.5
35	9.5	7.5	8.0	7.5	9.5	12.5	8.0
36	10.5	8.0	7.3	8.5	7.0	8.5	8.0
37	8.5	8.0	7.0	6.5	5.5	5.5	4.0
38	14.0	14.0	16.0	R	R	R	R
39	35.0	R	R	R	R	R	R
40	15.0	16.0	14.0	15.0	17.0	17.0	17.0
41	13.0	15.0	15.0	16.0	14.0	15.0	11.0
42	15.0	8.0	8.0	8.0	8.0	10.0	9.0
43	16.0	16.0	14.0	14.0	13.0	12.0	14.0
44	16.0	17.0	13.0	13.0	13.0	14.0	18.0
45	14.0	14.0	13.0	12.0	12.0	11.0	10.0
46	14.0	16.0	14.0	13.0	12.0	12.0	10.0
47	10.0	10.0	10.0	10.0	12.0	R	R
48	10.0	10.0	14.0	10.0	9.0	R	R
49	12.0	10	7	8	7	7	11
50	8.0	9.0	11.0	11.0	14.0	17.0	21.0
51	L	34.0	35.0	37.0	37.0	31.0	27.0
52	18.5	13.0	10.0	10.0	12.0	R	R
53	16.0	14.0	10.0	12.0	10.0	10.0	11.0
54	10.0	8.0	8.0	8.0	6.0	L	R

Appendix B10 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
55	10.0	12.0	R	R	R	R	R
56	12.0	14.0	-	-	-	-	-
57	12.0	14.0	14.0	13.0	L	L	L
58	20.0	L	L	L	L	16.0	14.0
59	14.0	36.0	52	46.0	50.0	36.0	50.0
60	42.0	31.0	30.0	33.0	50.0	44.0	50.0
61	12.0	10.0	12.0	10.0	10.0	R	R
62	20.0	16.0	17.0	20.0	18.0	24.0	R
63	16.0	18.0	16.0	18.0	18.0	17.0	20.0
64	20.0	20.0	24.0	R	R	R	R
65	24.0	22.0	21.0	22.0	17.0	17.0	R
66	22.0	29.0	18.0	17.0	16.0	14.0	16.0
67	20.0	17.0	17.0	18.0	14.0	14.0	16
68	11.5	14.0	16.0	14.0	14.0	14.0	21.0
69	14.0.	14.0	14.0	12.0	13.0	12.0	17.0
70	15.5	15.0	11.0	12.0	13.0	14.0	11.7
71	16.5	16.5	15.5	14.8	14.2	L	13.5
72	15.7	16.0	14.3	14.0	12.0	14.6	15.5
73	17.0	L	15.0	14.0	15.0	16.5	L
74	16.0	16.0	16.0	18.0	17.0	16.0	17.0
75	17.0	17.0	17.0	16.0	14.0	13.8	14.8
76	18.5	17.0	15.0	18.0	19.5	17.3	18.3
77	15.0	17.0	15.5	16.5	L	R	R

R = Bed rock reached

L = Soil sample cost

Appendix B11: Magnesium content of soils from Eastern  
Escarpment of Eritrea (meq/100 gm soil)

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
1	2.56	2.4	2.88	2.40	2.08	R	R
2	3.2	3.68	4.16	3.68	2.72	2.88	R
3	2.72	2.88	3.52	3.84	4.16	6.88	6.72
4	2.24	1.60	1.92	R	R	R	R
5	2.56	2.4	3.52	3.84	3.2	3.2	3.2
6	1.28	1.12	R	R	R	R	R
7	1.92	1.92	2.08	2.40	2.24	2.24	3.52
8	3.20	R	R	R	R	R	R
9	2.4	R	R	R	R	R	R
10	3.68	4.48	5.12	5.26	7.20=	7.68	9.28
11	5.12	8.32	1.04	10.24	11.04	11.04	12.16
12	1.92	1.60	1.76	R	R	R	R
13	2.24	2.24	3.20	3.04	R	R	R
14	2.24	R	R	R	R	R	R
15	2.40	1.92	1.92	R	R	R	R
16	2.08	1.76	1.60	1.44	1.60	1.28	
17	2.72	2.56	R	R	R	R	R
18	2.08	2.08	2.08	2.24	2.40	2.56	R
19	3.36	4.0	3.2	R	R	R	R
20	1.92	1.28	R	R	R	R	R
21	1.92	2.40	2.88	R	R	R	R
22	3.68	2.56	2.56	R	R	R	R
23	2.4	2.4	2.24	2.72	2.88	3.04	3.04
24	1.28	1.12	1.28	1.6	1.6	R	R
25	2.56	2.72	2.56	2.88	R	R	R
26	1.92	2.40	3.04	2.40	32.0	2.56	2.40

Appendix B11 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
27	2.56	2.56	2.24	3.2	2.88	2.08	2.88
28	2.72	3.04	2.88	2.56	2.24	2.40	2.40
29	2.56	2.24	2.40	6.08	2.40	R	R
30	2.24	2.72	2.56	2.88	2.24	2.24	1.92
31	3.04	2.72	3.36	4.96	4.32	5.28	3.52
32	2.08	2.08	2.08	2.24	2.24	2.56	2.56
33	2.72	2.88	4.8	2.72	2.72	2.56	R
34	2.24	3.84	1.40	2.72	3.04	3.20	3.20
35	3.52	2.56	3.36	2.88	3.84	4.64	3.20
36	3.52	2.56	2.56	3.04	2.72	3.04	2.72
37	3.20	2.88	2.24	2.24	1.76	1.60	1.28
38	5.92	5.28	6.72	R	R	R	R
39	2.72	R	R	R	R	R	R
40	4.32	5.44	4.32	4.64	5.76	5.76	6.40
41	4.16	4.48	1.16	4.80	4.64	4.80	4.48
42	4.16	3.68	3.84	4.48	4.80	5.92	5.92
43	4.64	5.76	6.24	6.88	6.24	7.36	9.6
44	6.08	5.92	5.76	5.28	5.76	7.2	5.92
45	4.64	4.00	4.16	4.00	4.48	4.64	4.32
46	7.68	5.44	7.04	4.64	6.08	4.80	6.08
47	5.28	4.32	2.88	2.16	2.88	R	R
48	4.16	3.36	3.52	1.92	2.08	R	R
49	3.20	3.04	1.92	2.40	2.24	4.32	6.08
50	2.4	2.4	2.08	1.76	1.92	2.24	2.24
51	3.84	2.24	2.24	2.08	2.24	2.24	1.76
52	2.88	2.56	1.60	1.60	1.28	R	R
53	5.76	4.16	3.20	3.36	3.04	3.04	3.20

Appendix B11 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
54	3.2	3.2	3.2	3.84	3.2	L	R
55	2.56	3.2	R	R	R	R	R
56	3.84	7.04	R	R	R	R	R
57	3.20	3.84	4.48	4.48	L	L	L
58	3.84	L	L	L	L	2.56	2.56
59	3.20	3.84	5.12	4.48	5.12	4.48	5.12
60	3.20	2.56	2.56	2.56	3.20	3.20	38.4
61	3.20	2.56	3.20	3.20	3.20	R	R
62	5.12	4.48	5.12	5.12=	4.48	6.64	R
63	4.48	4.48	4.48	5.12	5.76	6.4	6.4
64	7.04	7.04	8.96	R	R	R	R
65	6.4	7.04	6.4	6.4	6.4	7.04	R
66	5.76	5.76	5.12	4.48	3.84	3.84	4.48
67	5.12	4.48	3.84	4.48	4.48	4.48	4.48
68	4.8	5.28	5.12	5.12	4.48	3.84	R
69	3.84	3.20	3.20	3.20	3.20	3.20	4.48
70	5.12	4.48	4.0	4.48	4.80	4.96	4.64
71	5.44	5.60	5.76	6.4	6.72	L	5.76
72	6.56	5.44	5.44	4.96	5.12	6.40	6.40
73	5.76	L	5.92	6.08	5.76	6.40	L
74	5.44	6.40	6.88	8.0	8.0	9.28	8.84
75	6.08	5.92	5.44	5.92	6.24	6.24	7.36
76	5.44	5.60	5.40	5.40	5.92	5.76	5.92
77	5.60	5.76	6.40	7.84	2.56	R	R

R = Bed rock reached

L = Sample lost

Appendix B12: Sodium content of soils from Eastern  
Escarpment of Eritrea (meq/100 gm soil)

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
1	0.38	0.34	0.43	0.41	0.51	R	R
2	3.86	6.26	7.20	6.54	1.74	1.74	R
3	2.15	3.47	4.81	5.21	6.87	7.30	7.54
4	0.62	1.48	3.57	R	R	R	R
5	0.87	2.37	4.77	4.86	4.63	4.71	4.60
6	0.38	0.33	R	R	R	R	R
7	0.75	1.35	3.11	3.06	3.40	3.08	5.20
8	0.97	R	R	R	R	R	R
9	0.32	R	R	R	R	R	R
10	0.30	0.46	1.08	1.89	3.57	4.99	5.37
11	0.71	3.08	7.87	25.67	22.83	24.16	18.00
12	0.23	0.21	0.27	R	R	R	R
13	0.24	0.30	0.35	0.35	R	R	R
14	0.17	R	R	R	R	R	R
15	0.14	0.22	0.44	R	R	R	R
16	0.21	0.27	0.29	0.30	0.40	0.42	R
17	0.19	0.13	R	R	R	R	R
18	0.19	0.15	0.19	0.19	0.21	0.21	R
19	0.17	0.20	0.21	R	R	R	R
20	0.18	0.16	R	R	R	R	R
21	0.17	0.17	0.21	R	R	R	R
22	0.33	0.29	0.32	R	R	R	R
23	0.20	0.21	0.29	0.33	0.38	0.31	0.29
24	0.10	0.17	0.16	0.17	0.17	R	R
25	0.21	0.29	0.32	0.29	R	R	R
26	0.16	0.16	0.19	0.17	0.17	0.15	0.15
27	0.17	0.17	0.15	0.17	0.15	0.19	0.19

Appendix B12 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
28	0.14	0.17	0.14	0.16	0.16	0.17	0.19
29	0.17	0.22	0.22	0.24	0.27	R	R
30	0.14	0.19	0.19	0.19	0.16	0.17	0.16
31	0.17	0.21	0.24	0.21	0.21	0.24	0.22
32=	0.14	0.17	0.15	0.15	0.15	0.15	0.15
33	0.15	0.21	0.27	0.14	0.14	0.16	R
34	0.14	L	0.17	0.17	0.19	0.19	0.17
35	0.15	0.17	0.21	L=	0.21	0.27	0.27
36	0.15	0.17	0.17	0.20	0.31	0.20	0.14
37	0.14	0.17	0.16	0.13	0.12	0.15	0.09
38	0.15	0.16	0.19	R	R	R	R
39	0.22	R	R	R	R	R	R
40	0.15	0.17	0.17	0.17	0.22	0.24	0.26
41	0.15	0.17	0.17	0.19	0.21	0.21	0.22
42	0.16	0.17	0.10	0.16	0.17	0.21	0.21
43	0.17	0.19	0.19	0.21	0.22	0.21	0.22
44	0.21	0.24	0.18	0.21	0.21	0.22	0.27
45	0.14	0.21	0.17	0.17	0.17	0.15	0.15
46	0.17	0.19	0.21	0.19	0.24	0.22	0.21
47	0.12	0.12	0.22	0.19	0.24	R	R
48	0.11	0.12	0.12	0.19	0.22	R	R
49	0.14	0.22	0.19	0.22	0.24	0.24	0.32
50	0.13	0.16	0.19	0.21	0.22	0.25	0.35
51	0.17	0.27	0.27	0.22	0.26	0.22	0.22
52	0.14	0.15	0.15	0.14	0.22	R	R
53	0.17	0.17	0.17	0.15	0.15	0.15	0.17
54	0.16	0.37	0.39	0.45	0.45	L	R

Appendix B12 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
55	0.23	0.34	R	R	R	R	R
56	0.63	2.17	R	R	R	R	R
57	0.21	0.24	0.27	0.31	L	L	L
58	0.19	L	L	L	L	0.32	0.31
59	0.23	0.49	0.82	0.87	0.82	0.69	0.71
60	0.19	0.21	0.23	0.27	0.43	0.53	L
61	0.16	0.24	0.26	0.19	0.16	R	R
62	0.32	0.29	0.31	0.32	0.29	0.32	R
63	0.21	0.19	0.19	0.21	0.24	0.24	0.31
64	0.23	0.23	0.23	R	R	R	R
65	0.32	0.27	0.27	0.27	0.23	0.23	R
66	0.16	0.18	0.19	0.23	0.26	0.32	0.34
67	0.18	0.19	0.15	0.19	0.19	0.18	0.19
68	0.13	0.19	0.21	0.19	0.21	0.21	R
69	0.19	L	0.18	0.23	0.21	0.21	0.26
70	0.30	0.29	0.24	0.21	0.24	0.29	0.25
71	0.25	0.19	0.29	0.35	L	0.37	0.37
72	0.24	0.29	0.24	0.22	0.27	0.33	0.25
73	0.24	L	0.30	0.33	0.27	0.27	L
74	0.33	0.24	0.24	0.29	0.44	0.56	0.95
75	0.24	0.24	0.29	0.29	0.33	0.35	0.33
76	0.19	0.25	0.15	0.25	0.22	0.25	0.30
77	0.22	0.22	0.22	0.20	0.33	R	R

R = Bed rock reached  
L = Sample lost

Appendix B13: Manganese content of the soils from the  
Eastern Escarpment of Eritrea (meq/100 soil)

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
1	0.0175	0.021	0.007	0.0105	0.014	R	R
2	0.0175	0.0175	0.007	0.007	0.014	0.014 =	R
3	0.014	0.007	0.007	0.0105	0.007	0.007	L
4	0.0105	0.007	0.007	R	R	R	R
5	0.014	0.007	0.014	0.0105	0.0105	0.007	0.014
6	0.014	0.0105	R	R	R	R	R
7	0.0245	0.0175	0.014	0.014	0.0105	0.007	R
8	0.049	R	R	R	R	R	R
9	0.091	R	R	R	R	R	R
10	0.021	0.007	0.007	0.007	0.007	0.007	0.007
= 11	0.042	0.0105	0.014	0.007	0.007	0.007	0.007
12	0.0142	0.014	0.014	R	R	R	R
13	0.028	0.0105	0.014	0.014	R	R	R
14	0.056	R	R	R	R	R	R
15	0.019	0.035	0.014	R	R	R	R
16	0.028	0.021	0.014	0.007	0.007	0.007	R
17	0.056	0.018	R	R	R	R	R
18	0.063	0.0245	0.014	0.014	0.014	0.014	R
19	0.042	0.0245	0.021	R	R	R	R
20	0.0385	0.028	R	R	R	R	R
21	0.021	0.021	0.028	R	R	R	R
22	0.0175	0.014	0.0175	R	R	R	R
23	0.0315	0.0245	0.0105	0.0105	0.0105	0.014	0.0105
24	0.035	0.021	0.014	0.007	0.007	R	R
25	0.021	0.007	0.105	0.04	R	R	R
26	0.035	0.028	0.028	0.014	0.0245	0.028	0.021

Appendix B13 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
27	0.028	0.028	0.0175	0.021	0.0175	0.014	0.0175
28	0.0455	0.028	0.0245	0.028	0.028	0.028	0.035
29	0.0455	0.028	0.021	0.021	0.0245	R	R
30	0.0665	0.0385	0.028	0.035	0.021	0.021	0.021
31	0.0525	0.0315	0.0315	0.0245	0.028	0.028	L
32	0.028	0.028	0.0245	0.014	0.0175	0.0245	0.021
33	0.028	0.028	0.0245	0.0175	0.014	0.021	R
34	0.042	0.028	0.021	0.014	0.0175	0.014	0.0175
35	0.049	0.014	0.021	0.014	0.0245	0.028	0.021
36	0.049	0.021	0.028	0.021	0.0245	0.021	0.014
37	0.021	0.028	0.0245	0.028	0.0175	0.021	0.0245
38	0.021	0.0175	0.0245	R	R	R	R
39	0.0385	R	R	R	R	R	R
40	0.0175	0.028	0.028	0.0385	0.0455	0.028	0.0245
41	0.014	0.021	0.0105	0.0105	0.0105	0.007	0.0105
42	0.035	0.014	0.0175	0.105	0.014	0.105	0.007
43	0.0385	0.0245	0.007	0.021	0.0105	0.0105	0.0105
44	0.028	0.0175	0.0245	0.0105	0.014	0.008	0.0105
45	0.021	0.0245	0.014	0.0175	0.014	0.014	0.014
46	0.028	0.021	0.0315	0.018	0.021	0.014	0.014
47	0.0245	0.0105	0.0105	0.014	0.014	R	R
48	0.035	0.0245	0.0105	0.014	0.0175	O R	R
49	0.042	0.0175	0.0105	0.007	0.014	0.014	0.021
50	0.021	0.0175	0.0105	0.0105	0.007	0.007	0.0105
51	0.021	0.0245	0.021	0.014	0.014	0.014	0.014
52	0.042	0.0245	0.021	0.0175	0.021	R	R
53	0.056	0.0385	0.0315	0.021	0.014	0.007	0.014

Appendix B13 continued

Stand No.	Depth in cms.						
	10	20	30	40	50	60	70
54	0.042	0.0175	0.021	0.021	0.0245	L	R
55	0.035	0.021	R	R	R	R	R
56	0.07	0.0875	R	R	R	R	R
57	0.035	0.042	0.0175	0.014	L	L	L
58	0.028	L	L	L	L	0.021	0.021
59	0.014	0.0175	0.035	0.035	0.035	0.035	0.028
60	0.0385	0.035	0.035	0.035	0.042	0.042	0.0385
61	0.028	0.021	0.028	0.0245	0.021	R	R
62	0.0665	0.035	0.042	0.035	0.0315	0.035	R
63	0.042	0.028	0.0175	0.021	0.0175	0.021	0.0175
64	0.01995	0.161	0.0805	R	R	R	R
65	0.054	0.0805	0.168	0.14	0.098	0.0455	R
66	0.0805	0.035	0.0315	0.021	0.014	0.014	0.0175
67	0.0735	0.028	0.0175	0.0245	0.014	0.014	0.014
68	0.049	0.049	0.315	0.021	0.0245	0.021	R
69	0.021	0.014	0.014	0.007	0.007	0.007	0.0105
70	0.028	0.021	0.014	0.0175	0.014	0.014	0.014
71	0.028	0.021	0.021	0.014	0.0175	L	0.014
72	0.049	0.0315	0.021	0.0175	0.0175	0.021	0.021
73	0.0385	L	0.0175	0.0175	0.014	0.0175	R
74	0.049	0.035	0.035	0.021	0.021	L	0.014
75	0.0245	0.014	0.0175	0.014	0.014	0.0175	0.014
76	0.028	0.0315	0.0175	0.014	0.021	0.021	0.021
77	0.028	0.028	0.0245	0.028	0.014	R	R

R = Bed rock reached

L = Sample lost

Appendix C1 : Comparison of the stand groups by altitude (using t-test)

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B	17	-341	4.543	0.001	D - E	16	271	5.847	0.001
C	10	-230	7.369	0.001	F	13	642	16.261	0.001
D	9	176	8.743	0.001	G	11	572	2.524	0.05
E	17	447	10.12	0.001	H	8	984	441.25	0.001
F	14	818	21.35	0.001	I	7	1028	101.58	0.001
G	12	748	3.629	0.005	J	11	1198	708.71	0.001
H	9	1168	55.52	0.001	E - F	21	371	9.252	0.001
I	8	1204	49.61	0.001	G	19	301	2.141	0.05
B - C	16	111	1.42	-	I	15	757	14.466	0.001
D	15	517	6.075	0.001	J	19	927	25.440	0.001
E	23	788	13.26	0.001	F - G	16	70	0.040	-
F	23	788	13.26	0.001	H	13	342	8.614	0.001
G	18	1098	6.956	0.001	I	12	386	8.941	0.001
H	15	1501	17.621	0.001	J	16	556	18.94	0.001
I	14	1545	16.144	0.001	G - H	11	412	1.823	-
J	18	1715	25.728	0.001	I	7	456	1.495	-
C - D	9	406	15.744	0.001	J	10	626	3.002	0.025
E	17	677	15.635	0.001	H - I	7		3.580	0.010
F	14	1048	27.608	0.001	J	11	214	28.72	0.001
G	12	978	4.747	0.001	I - J	10	170	17.672	0.001

d.f. = Degree of freedom  
 $\bar{X}_1 - \bar{X}_2$  = Difference between the means of the groups compared.  
t = Calculated t value  
P = Probability level of significance

Appendix C2: Comparison of the stand groups by slope (using t-test)

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B	16	-9	2.088	-	D - E	16	6.8	2.212	0.05
C	10	-29.5	1.926	-	F	13	2.3	0.705	-
D	9	-13	0.354	-	G	11	3.4	0.523	-
E	17	-62	0.015	-	H	8	17.6	5.33	0.001
F	14	-10.7	0.375	-	I	7	20.9	3.406	0.025
D	12	-9.6	0.571	-	J	11	24.8	8.435	0.001
H	9	-4.6	0.128	-	E - F	21	-4.5	1.762	-
I	8	7.9	1.155	-	G	19	-3.4	1.255	-
J	12	11.8	3.078	0.005	H	16	10.8	2.521	0.05
B - C	16	-20.8	5.697	0.001	I	15	14.1	3.187	0.01
D	15	04.0	0.983	-	J	19	18.0	7.089	0.001
E	23	-2.8	0.074	-	F - G	16	1.1	0.377	-
F	20	-1.7	0.534	-	H	13	15.3	4.769	0.001
G	18	-0.6	1.75	-	I	12	18.6	3.818	0.005
H	15	13.6	3.375	0.005	J	16	22.5	8.315	0.001
I	14	16.9	3.125	0.010	G - H	11	14.2	4.339	0.005
J	18	20.8	6.322	0.001	I	7	17.5	3.344	0.025
C - D	9	16.5	6.702	0.001	J	10	21.4	7.657	0.001
E	17	23.7	8.937	0.001	H - I	7	3.3	0.545	-
F	14	18.8	6.894	0.001	J	11	7.2	2.517	0.05
G	12	19.9	7.361	0.001	I - J	10	3.9	0.793	-
H	9	34.1	14.98	10.001					
I	8	37.4	7.284	0.001					

d.f. = Degree of freedom.

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

t = The calculated t value

P = probability level of significance

Appendix C 3: Comparison of the stand groups by % of rock cover of the surface (using t-test)

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B	16	19	1.246	-	D - E	16	12	-0.938	-
C	10	6	0.4309	-	F	13	-19	1.759	-
D	9	14	0.8702	-	G	11	-25	2.292	0.05
E	17	26	2.421	0.05	H	8	-8	0.509	-
F	14	-5	0.598	-	I	7	30	1.147	-
G	12	-1	1.373	-	J	11	15	0.757	-
H	9	6	0.498	-	E - F	21	-31	1.727	-
I	8	44	2.004	-	G	19	-37	4.737	0.001
J	12	29	1.704	-	H	16	-20	1.863	-
B - C	16	-19	1.065	-	I	15	18	1.097	-
D	15	-5	0.363	-	J	19	3	0.238	-
E	23	-7	0.110	-	F - G	16	-6	1.379	-
F	20	-24	2.916	0.05	H	13	11	1.525	-
G	18	-30	3.496	0.005	I	12	49	3.217	0.01
H	15	-13	1.108	-	J	16	34	2.782	0.025
I	14	25	1.423	-	G - H	11	17	2.811	0.025
J	18	10	0.743	-	I	7	55	3.413	0.025
C - D	9	8	0.467	-	J	10	40	3.267	0.01
E	17	20	1.770	-	H - I	7	38	1.692	-
F	14	-11	0.893	-	J	11	23	1.304	-
G	12	-17	1.845	-	I - J	10	-15	0.609	-
H	9	0	-	-					
I	8	38	1.657	-					
J	12	23	1.306	-					

d.f. = Degree of freedom.

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

t = The calculated t-value

P = Probability level of significance

Appendix C4: Comparison of groups of stands by soil texture - % of sand  
(using t-test)

Groups Compared	Surface			Average				
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B	16	-5.25	3.088	0.01	16	-5.16	2.150	0.05
C	10	1.04	0.520	-	10	1.6	0.337	-
D	9	-4.02	0.847	-	9	-8.22	2.119	-
E	17	-0.43	0.160	-	17	-1.75	0.383	-
F	14	-0.03	0.009	-	14	-	-	-
G	12	2.38	0.732	-	11	2.12	0.551	-
H	9	1.23	0.287	-	8	2.12	0.465	-
I	8	14.69	3.173	-	7	8.58	1.766	-
J	12	8.66	2.112	-	11	6.59	1.417	-
B - C	16	6.29	3.610	0.005	16	6.76	2.805	0.025
D	15	1.66	0.737	-	15	-3.06	2.833	0.025
E	23	5.25	3.780	0.001	23	4.01	2.673	0.05
F	20	5.65	3.571	0.005	20	5.16	3.004	0.001
G	18	8.06	4.903	0.001	17	7.28	4.886	0.001
H	15	6.31	3.071	0.01	14	11.75	6.088	0.001
I	14	2.37	10.609	0.001	17	7.28	4.380	0.001
J	18	14.34	5.806	0.001	17	11.75	6.088	0.001
C - D	9	-4.63	0.99	-	9	-9.82	6.08	0.001
E	17	-1.04	0.605	-	17	-2.75	0.917	-
F	14	-0.9	0.405	-	14	-1.60	0.471	-
G	12	1.77	0.976	-	11	0.52	0.136	-
H	9	0.22	0.008	-	8	0.52	0.115	-
I	8	14.08	5.655	0.001	7	16.98	1.806	-
J	12	8.05	2.025	0.025	11	4.99	1.238	-

Appendix C4 continued

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
D - C	16	3.59	1,617	-	16	7.07	3,123	0.01
F	13	3.99	1,433	-	13	8.22	3,167	0.01
G	11	6.4	2,486	0.050	9	10.34	4,066	0.001
H	8	-4.65	1,383	-	7	-10.34	4,231	0.005
I	7	18.71	5,285	0.001	6	26.8	2,968	0.025
J	11	12.68	3,337	0.001	10	14.81	4,904	0.001
E - F	21	0.4	0.237	-	21	1.15	0.543	-
G	19	2.81	1,797	-	18	3.27	1,399.5	-
H	16	1.03	0.507	-	15	3.27	1,258	-
I	15	5.12	7.27	0.001	14	19.73	3,338.4	0.05
J	19	9.09	4,004	0.001	18	7.4	3,108	0.01
F - G	16	2.41	1,221	-	15	2.12	0,744	-
H	13	0.66	0,255	-	12	2.12	0,368	-
I	12	14.72	5,432	0.001	14	8.63	3,384	0.005
J	16	8.69	3,183	0.010	15	6.59	2,399	0.05
G - H	11	-1.75	0,763	-	9	0.00	-	-
I	10	12.31	5,113	0.001	5	16.46	2,059	-
J	14	6.28	2,620	0.0025	12	4.47	1,449	-
H - I	7	14.06	4,550.1	0.001	5	16.46	2,059	-
J	11	8.03	2,243	0.05	9	4.47	1,24	-
I - J	10	-6.03	1,562	1	18	-11.99	1,460	-

d.f. Degree of freedom.

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

t The calculated t value

P Probability level of significance

Appendix C5: Comparison of the groups of stands by soil texture -  
% of silt (using t-test)

Groups Compared	Surface				Average			
	d. f.	$\bar{X}_1 - \bar{X}_2$	T	P	d. f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B	16	-1.61	1.103	-	16	1.94	0.966	-
C	10	-2.86	1.589	-	10	-2.7	1.179	-
D	9	-1.12	0.364	-	9	4.86	3.096	0.025
E	17	-0.97	0.032	-	17	-0.16	0.067	-
F	14	-0.71	0.261	-	14	-1.22	0.401	-
G	12	-4.90	1.872	-	11	-4.95	1.506	-
H	9	-3.81	1.217	-	8	-3.94	1.985	-
I	8	-13.11	2.373	0.05	7	-11.94	1.985	-
J	12	-9.77	2.825	0.05	11	-5.13	1.655	-
B - C	16	-4.47	3.216	0.01	16	-4.64	2.900	0.025
D	15	-0.34	0.193	-	15	2.90	3.767	0.005
E	23	-1.61	1.310	-	23	-2.100	1.963	-
F	20	-2.25	1.535	-	20	-3.16	2.003	-
G	18	-6.44	4.304	0.001	17	-6.89	4.745	0.001
H	15	-5.35	4.650	0.001	14	-5.88	7.259	0.001
I	14	-15.33	4.746	0.001	13	-13.18	4.423	0.001
J	18	-11.31	5.600	0.001	17	-7.07	5.702	0.001
C - D	9	4.13	1.707	-	9	7.56	2.989	0.025
E	17	2.86	1.744	-	17	2.54	1.588	-
F	14	2.16	0.989	-	14	1.18	0.435	-
G	12	-1.97	1.043	-	11	-2.25	0.796	-
H	9	-0.88	0.429	-	8	-1.24	0.432	-
I	8	-10.86	0.744	-	7	-8.54	1.579	-
J	12	-6.84	2.319	0.05	11	-2.43	0.935	-

Appendix C5 continued

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
D - E	16	-1.27	0.641	-	16	-5.00	-6.173	0.001
F	13	-1.97	0.760	-	13	-11.24	4.684	0.001
G	11	-6.1	2.586	0.025	9	-9.79	2.578	0.025
H	8	-5.01	1.887	-	7	-8.78	7.439	0.001
I	7	-14.99	2.532	0.05	6	-16.08	3.262	0.025
J	11	-10.97	3.226	0.01	10	-9.094	4.786	0.001
E - F	21	-0.64	0.378	-	21	-1.06	0.542	-
G	19	-4.83	3.017	0.010	18	-4.19	2.578	0.025
H	16	-3.74	2.020	-	15	-3.78	2.100	-
I	15	-13.72	3.811	0.01	11	-1.09	3.214	0.01
J	19	-9.7	4.409	0.001	18	-4.97	2.096	0.010
F - G	16	-4.19	2.040	-	15	-3.73	1.529	-
H	13	-3.1	1.260	-	12	-2.73	1.026	-
I	12	-13.08	2.979	0.02	11	-10.02	2.258	0.05
J	16	-9.06	3.393	0.005	15	-3.91	1.763	-
G - H	11	-1.09	0.502	-	9	1.01	0.403	-
I	10	-8.87	1.638	-	8	-6.29	1.294	-
J	14	-4.87	1.787	-	12	-0.18	0.080	-
H - I	7	-9.98	1.721	-	5	-7.30	1.311	-
J	1.1	-5.96	1.801	-	9	-1.19	0.569	-

d.f. = Degree of freedom

$X_1 - X_2$  = The difference between the means of the groups compared

t = The calculated t value

P = Probability level of significance.

Appendix C6: Comparison of groups of stands by soil texture - % of clay (using t-test)

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B	16	3.64	6.500	0.001	16	3.12	3.90	0.005
C	10	11.82	2.246	0.05	10	0.93	0.531	-
D	9	1.82	1.556	-	9	3.22	3.105	0.025
E	17	0.50	0.71	-	17	1.15	1.264	-
F	14	0.32	0.339	-	14	0.95	1.025	-
G	12	1.52	1.119	-	11	2.15	0.998	-
H	9	2.22	1.760	-	8	1.12	0.700	-
I	8	1.9	0.605	-	7	7.23	-1.592	-
J	12	-0.27	0.229	-	11	0.68	-0.472	-
B - C	16	-1.82	2.800	0.025	16	2.12	-2.078	-
D	15	-1.32	1.833	-	15	0.10	-0.154	-
E	23	-3.64	8.088	0.001	23	1.97	-3.200	0.005
F	20	-3.44	6.143	0.001	20	2.10	-3.331	0.005
G	18	-1.62	1.737	-	17	0.90	-1.168	-
H	15	-0.94	1.205	-	14	2.00	-1.923	-
I	14	-5.04	2.681	0.025	13	10.39	-3.981	0.005
J	18	-3.41	4.372	0.001	17	3.73	-1.120	-
C - D	9	0.5	0.47	-	9	2.29	1.579	-
E	17	-1.82	2.84	0.025	17	0.22	0.200	-
F	14	-1.3	1.469	-	14	0.02	0.017	-
G	12	0.2	0.153	-	11	1.22	0.849	-
H	9	0.88	0.765	-	8	0.19	0.096	-
I	8	-3.22	1.039	-	7	8.27	-1.969	-
J	12	-1.59	1.420	-	11	1.61	-0.976	-

Appendix C6 continued

Groups Compared	Surface				Average			
	d.f.	$X_1 - X_2$	T	P	d.f.	$X_1 - X_2$	T	P
D - E	16	-2.32	3.268	0.005	16	2.07	-2.326	0.050
F	13	-2.12	2.168	0.050	13	2.27	-2.926	.025
G	11	-0.3	0.208	-	9	1.07	-1.121	-
H	8	0.38	0.300	-	7	2.10	-1.388	-
I	7	-3.72	1.088	-	6	10.56	-2.496	0.025
J	11	-2.08	1.342	-	10	-3.90	2.910	-
E - F	21	0.2	0.337	-	21	-3.1	4.492	0.001
G	19	2.02	2.313	0.05	18	1.00	0.642	-
H	16	2.7	3.53	0.005	15	-0.03	0.026	-
I	15	-1.40	0.71	-	14	-8.49	3.253	-
J	19	-0.23	0.307	-	18	-1.83	1.830	-
F - G	16	1.82	0.169	-	15	1.2	1.380	-
H	13	2.55	2.467	0.05	12	0.17	0.143	-
I	12	-1.6	0.672	-	11	-8.27	2.802	0.025
J	16	-0.03	0.032	-	15	-1.63	1.589	-
G - H	11	0.68	0.455	-	9	1.03	0.684	-
I	10	-3.42	1.019	-	8	9.49	-2.605	-
J	14	-1.79	1.376	-	12	2.83	-2.180	-
H - I	7	-4.1	1.171	-	5	8.46	-1.662	-
J	11	-2.47	1.918	-	9	1.80	-0.994	-
I - J	10	1.63	0.588	-	8	6.66	1.739	-

d.f. = Degree of freedom.

$X_1 - X_2$  = The difference between the means of the groups compared

t = The calculated t value

P = Probability level of significance.

Appendix C7: Comparison of the stand groups by soil color - Hue  
(using t-test)

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B	16	-0.62	-1.322	-	16	-0.95	1.973	-
C	10	0	0	-	10	-0.49	0.618	-
D	9	-0.83	-1.423	-	9	-1.04	-1.462	-
E	17	1.09	1.534	-	17	-0.18	-0.132	-
F	14	-0.58	2.180	0.05	14	0.2	0.573	-
G	12	-0.83	2.578	0.025	11	-1.04	1.669	-
H	9	-0.83	0.901	-	8	-1.14	0.972	-
I	8	-0.83	1.909	-	7	-1.04	3.142	0.025
J	12	-1.46	4.126	0.005	11	-1.81	1.869	-
B - C	16	0.62	1.323	-	16	0.46	1.479	-
D	15	-0.21	1.035	-	15	0.09	0.613	-
E	23	1.71	3.589	0.005	23	0.77	2.800	0.025
F	20	0.04	0.165	-	20	1.55	4.055	0.001
G	18	-0.21	1.448	-	17	0.09	0.403	-
H	15	-0.21	0.358	-	14	-0.19	0.332	-
I	14	-0.21	0.564	-	13	-0.09	0.471	-
J	18	-0.84	1.487	-	17	-0.86	1.585	-
C - D	9	-0.83	1.423	-	9	-0.55	1.213	-
E	17	1.09	1.534	-	17	0.3	0.674	-
F	14	-0.58	1.126	-	14	0.69	1.376	-
G	12	-0.83	1.842	-	11	-0.55	1.459	-
H	9	-0.83	0.901	-	8	-0.65	0.677	-
I	8	-0.83	1.259	-	7	-0.55	0.916	-
J	12	-1.46	1.704	-	11	-1.32	1.542	-

Appendix C7: continued

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
D - E	16	1.92	2.902	0.025	16	0.86	2.097	-
F	13	0.25	0.723	-	13	1.24	2.971	0.025
G	11	0	0	-	9	0	0	-
H	8	0	0	-	7	-0.10	0.111	-
I	7	0	0	-	6	0	0	-
J	11	-0.63	-0.819	-	10	-0.77	0.907	-
E - F	21	-1.67	3.193	0.005	21	0.38	0.967	-
G	19	-1.92	3.592	0.005	18	0.86	2.496	0.025
H	16	-1.92	2.326	0.05	15	-0.96	1.375	-
I	15	-1.92	2.508	0.025	14	-0.86	1.611	-
J	19	-2.55	3.540	0.005	18	-1.63	1.633	-
F - G	16	-0.25	0.892	-	15	-1.24	3.148	0.01
H	13	-0.25	0.387	-	2	-1.34	1.681	-
I	12	-0.25	0.620	-	11	-1.24	2.269	0.05
J	16	-0.88	-1.417	-	15	-2.01	2.834	0.025
G - H	11	0	0	-	9	-0.100	10.136	-
I	7	0	0	-	5	0	0	-
J	10	-0.63	1.009	-	8	-0.770	1.089	-
H - I	7	0	0	-	5	0.10	0.082	-
J	11	-0.63	0.626	-	9	-0.67	0.553	-
I - J	10	-3.12	-3.448	0.01	8			

d.f. = Degree of freedom

$X_1 - X_2$  = The difference between the means of the groups compared

t = The calculated t value

P = Probability level of significance

Appendix C8: Comparison of the stand groups by soil color - Value  
(using t-test)

Groups Compared	Surface			Average				
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B	16	-1.84	1.186	-	16	0.07	0.182	-
C	10	1.16	3.102	0.025	10	1.14	2.478	0.05
D	9	1.16	2.133	-	9	-0.13	0.31	-
E	17	1.03	0.845	-	17	-0.15	0.429	-
F	14	0.37	0.075	-	14	-0.54	1.667	-
G	12	0.03	0.080	-	11	-0.28	0.739	-
H	9	-0.03	0.379	-	8	-0.27	0.491	-
I	8	-0.17	0.338	-	7	-0.06	0.118	-
J	12	-0.42	1.069	-	11	-0.12	0.356	-
B - C	16	3.00	3.619	0.01	16	1.07	3.262	0.005
D	15	2.87	3.099	0.01	15	-0.20	0.645	-
E	23	2.21	3.746	0.005	23	-0.22	0.764	-
F	20	2.87	2.812	0.025	20	-0.61	2.234	0.05
G	18	2.81	2.479	0.025	17	-0.35	0.9	-
H	15	1.67	1.819	-	14	-0.34	0.722	-
I	14	1.67	1.657	-	13	-0.13	0.262	-
J	18	1.42	1.945	-	17	-0.19	0.597	-
C - D	9	-0.13	0.314	-	9	-1.27	2.90	0.025
E	17	-0.79	2.23	0.050	17	-1.29	3.634	0.005
F	14	-1.13	3.113	0.01	14	-1.68	5.094	0.001
G	12	-1.19	3.718	0.005	11	-1.42	3.532	0.005
H	9	-1.33	3.575	0.01	8	-1.41	2.474	0.05
I	8	-1.33	3.182	0.025	7	-1.20	2.230	-
J	12	-1.58	4.606	0.001	11	-1.26	3.49	0.005

Appendix C8 continued

Groups Compared	Surface				Agerage			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
D - E	16	-0.66	1.579	-	16	-0.02	0.060	-
F	13	-1.0	2.273	0.05	13	-0.41	1.336	-
G	11	-1.06	2.819	0.025	9	-0.15	0.374	-
H	8	-1.20	2.449	0.05	7	-0.14	0.269	-
I	7	-1.20	2.158	-	6	0.07	0.151	-
J	11	-1.45	3.364	0.01	10	0.01	0.032	-
E - F	21	-0.34	-1.030	-	21	-0.39	1.573	-
G	19	-0.40	1.278	-	18	-0.13	0.428	-
H	16	-0.44	1.388	-	15	0.12	0.283	-
I	15	-0.44	1.197	-	14	0.08	0.214	-
J	19	-0.69	2.446	0.025	18	0.02	0.107	-
F - G	16	-0.06	0.175	-	15	0.26	0.932	-
H	13	-0.20	0.475	-	12	0.27	0.689	-
I	12	-0.20	0.426	-	11	0.48	1.277	-
J	15	-0.45	1.261	-	15	0.42	1.654	-
G - H	11	-0.14	0.396	-	9	0.01	0.021	-
I	7	-0.14	0.327	-	5	0.22	0.268	-
J	10	-0.39	1.157	-	8	0.16	0.576	-
H - I	7	0	0	-	5	0.21	0.172	-
J	11	-0.25	0.648	-	9	0.15	0.362	-
I - J	10	-0.25	1.412	-	8	0.06	0.186	-

d.f. = Degree of freedom

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

t = The calculated t value

p = Probability level of significance

Appendix C9: Comparison of the stand groups by soil color - Chroma  
(using t-test)

Groups Compared	Surface				Average			
	d. f.	$\bar{X}_1 - \bar{X}_2$	T	P	d. f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B	16	1.83	2.260	0.05	16	0.32	0.522	-
C	10	3.67	3.998	0.005	10	1.58	2.010	-
D	9	1.12	1.000	-	9	0.07	0.080	-
E	17	2.38	3.700	0.005	17	0.08	0.126	-
F	14	2.70	3.253	0.010	14	-0.24	-0.274	-
G	12	2.25	2.090	-	11	0.82	0.900	-
H	9	2.20	6.940	0.001	8	0.44	0.407	-
I	8	1.75	1.265	-	7	0.41	0.315	-
J	12	2.62	3.075	0.01	11	1.37	1.713	-
B - C	16	1.84	3.376	0.005	16	1.26	2.700	0.025
D	15	-0.63	-1.613	-	15	-0.25	0.48	-
E	23	0.55	1.368	-	23	-0.24	0.603	-
F	20	0.87	1.667	-	20	-0.55	0.988	-
G	18	0.42	0.724	-	17	0.5	0.870	-
H	15	0.37	0.523	-	14	0.12	0.184	-
I	14	-0.08	-0.094	-	13	0.09	0.115	-
J	18	0.79	1.17	-	17	1.05	2.13	0.05
C - D	9	-2.47	4.75	0.005	9	-1.51	2.48	0.05
E	17	-1.29	14.271	0.001	17	-1.50	3.018	0.01
F	14	-0.97	1.917	-	14	-1.82	2.447	0.05
G	12	-1.42	2.544	0.05	11	-0.76	1.032	-
H	9	-1.47	2.286	0.05	8	-1.14	1.423	-
I	8	-1.92	2.240	-	7	-1.17	1.201	-
J	12	-1.05	2.290	0.05	11	-0.21	0.353	-

Appendix C9 continued

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
D - E	16	1.18	2.256	0.05	16	-0.01	0.018	-
F	13	1.5	2.066	-	13	-0.31	0.364	-
G	11	1.05	1.295	-	9	0.75	0.911	-
H	8	0	0	-	7	0.37	0.408	-
I	7	0.55	0.447	-	6	0.34	0.304	-
J	11	1.42	2.023	-	10	1.30	1.943	-
E - F	21	0.32	1.610	-	21	-0.32	0.560	-
G	19	-0.13	0.310	-	18	0.74	1.261	-
H	16	-0.18	0.368	-	15	0.36	0.333	-
I	15	-0.63	1.019	-	14	0.33	0.407	-
J	19	0.24	0.709	-	18	1.29	2.512	0.025
F - G	16	-0.45	0.782	-	15	1.06	1.297	-
H	13	-0.5	0.725	-	12	0.68	0.687	-
I	12	-0.95	1.118	-	11	0.65	0.551	-
J	16	-0.08	10.159	-	15	1.61	2.181	0.05
G - H	11	-0.05	0.065	-	9	-0.38	0.377	-
I	7	-0.5	0.525	-	5	-0.41	0.340	-
J	10	0.37	0.665	-	8	0.55	0.735	-
H - I	7	0.45	0.256	-	5	-0.03	0.021	-
J	11	0.42	1.745	-	9	0.93	1.095	-
I - J	10	0.87	1.04	-	8	0.96	0.934	-

d.f. = Degree of freedom

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

t = The calculated t value

P = Probability level of significance

Appendix C10: Comparison of the stand groups by soil pH  
(using t-test)

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B	16	0.16	0.516	-	16	0.19	0.704	-
C	10	0.44	0.978	-	10	0.55	1.410	-
D	9	-0.23	0.677	-	9	-0.62	2.480	0.05
E	17	0.36	1.440	-	17	-0.01	0.045	-
F	14	0.44	1.781	-	14	0.15	0.837	-
G	12	-0.24	0.753	-	11	-0.24	0.678	-
H	9	0.12	0.353	-	8	-0.42	1.615	-
I	8	-0.43	1.229	-	7	-0.76	2.621	0.050
J	12	-0.74	2.467	0.05	11	-0.65	2.826	0.025
B - C	16	0.6	1.463	-	16	0.37	1.121	-
D	15	-0.42	1.24	-	15	-0.81	2.893	0.025
E	23	0.16	0.73	-	23	-0.20	1.00	-
F	20	0.24	1.080	-	20	-0.04	0.197	-
G	18	-0.44	1.447	-	17	-0.43	1.398	-
H	15	0.32	0.941	-	14	-0.61	2.033	-
I	14	-0.63	1.909	-	13	-0.95	2.714	0.025
J	18	-0.94	3.241	0.005	17	-0.84	3.360	0.005
C - D	9	-1.02	2.116	-	9	-1.17	3.00	0.05
E	17	-0.44	1.375	-	17	-0.53	1.893	-
F	14	-0.36	1.054	-	14	-0.4	1.474	-
G	12	-1.04	2.507	0.05	11	-0.79	1.830	-
H	9	-0.92	1.878	-	8	-0.97	2.256	-
I	8	-1.23	2.321	0.05	7	-1.31	2.62	0.05
J	12	-1.54	3.85	0.005	11	-1.2	3.529	0.005

Appendix C10 continued

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
D - B	16	-0.58	2.710	0.025	16	-0.61	2.905	0.005
F	13	0.66	3.474	0.005	13	0.77	5.531	0.001
G	11	-0.02	0.072	-	9	0.38	1.132	-
H	8	0.1	0.403	0.005	7	0.17	0.920	-
I	7	-0.21	0.955	-	6	-0.14	0.700	-
J	11	-0.52	2.167	-	10	-0.03	0.150	-
E - F	21	0.08	0.501	-	21	0.16	1.068	-
G	19	-0.6	2.881	0.01	16	-2.23	0.893	-
H	16	0.48	2.190	0.05	15	-0.41	1.864	-
I	15	-0.79	3.591	0.005	14	-0.75	2.885	0.025
J	19	-1.1	5.789	0.001	18	-0.64	3.368	0.005
F - G	16	-0.68	3.433	0.005	15	-0.47	1.864	-
H	13	-0.56	2.841	0.025	12	-0.60	4.397	0.001
I	12	-0.87	4.833	0.001	11	-0.91	5.703	0.001
J	16	-1.88	10.444	0.001	15	-0.80	5.614	0.001
G - H	11	0.12	0.424	-	9	-0.18	1.012	-
I	10	-0.19	0.698	-	8	-0.52	1.161	-
J	14	-0.5	2.00	-	12	-0.41	1.755	-
H - I	7	-0.31	1.348	-	5	-0.31	1.820	-
J	11	-0.62	2.480	0.05	9	-0.2	0.952	-
I - J	10	-0.31	1.030	-	8	-0.11	0.458	-

d.f. = Degree of freedom

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

t = The calculated t values

P = Probability level of significance

Appendix C11: Comparison of the stand groups by soil  
Conductivity (using t-test)

Groups									
Compared	d.f.	$\bar{X}_1$	$\bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B	16	0.02		2.00	-	16	0.348	2.175	0.05
C	10	0.275		1.964	-	10	0.30	1.25	-
D	9	0.045		1.047	-	9	0.36	1.440	-
E	17	0.085		7.083	0.001	17	0.39	1.855	-
F	14	0.07		6.153	0.001	14	0.398	2.131	0.05
G	12	0.071		5.030	0.001	11	0.39	1.855	-
H	9	0.03		1.154	-	8	0.382	1.317	-
I	8	-0.15		1.364	-	7	0.205	0.661	-
J	12	-0.613		0.807	-	11	-1.12	2.286	0.05
B - C	16	-0.255		2.833	0.025	16	-0.056	0.800	-
D	15	-0.02		1.33	-	15	0.01	0.167	-
E	23	0.02		2.00	-	23	0.062	2.067	0.05
F	20	0.005		0.562	-	20	0.05	1.241	-
G	18	0.006		4.962	0.001	17	0.004	0.843	-
H	15	-0.935		46.45	0.001	14	0.034	0.567	-
I	14	-0.215		3.308	0.005	13	-0.143	1.788	-
J	18	-0.678		2.421	0.05	17	-1.468	4.735	0.001
C - D	9	0.235		-1.567	-	9	0.058	0.725	-
E	17	0.275		0.982	-	17	1.11	2.200	0.05
F	14	0.26		2.540	0.025	14	0.106	1.958	-
G	12	0.26		2.261	0.05	11	0.088	1.340	-
H	9	0.22		1.467	-	8	0.082	0.911	-
I	8	0.04		0.071	-	7	-0.095	0.792	-
J	12	-0.423		1.007	-	11	-1.42	3.227	0.010

Appendix C 11 continued

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
D - E	16	0.04	3.077	0.010	16	0.052	2.600	0.025
F	13	-0.025	2.002	-	13	-0.04	0.699	-
G	11	-0.026	1.671	-	9	-0.03	4.066	0.005
H	8	-0.015	0.530	-	7	0	0	-
I	7	-0.195	1.625	-	6	-0.153	-2.550	.005
J =	11	-0.658	1.645	-	10	-1.478	3.079	0.025
E - F	21	-0.015	1.755	-	21	-0.012	1.482	-
G	19	-0.014	1.343	-	18	0.022	2.340	0.05
H	16	-0.055	3.056	0.01	15	0.028	7.000	0.001
I	15	-0.235	3.456	0.005	14	-0.205	6.833	0.001
J	19	-0.698	2.585	0.025	18	-1.53	5.276	0.001
F - G	16	0.001	0.103	-	15	-0.010	1.443	-
H	13	-0.04	1.874	-	12	10.016	1.566	-
I	12	-0.22	2.750	0.025	11	-0.193	4.744	0.001
J	19	-0.06	0.194	-	15	-1.518	4.780	0.001
G - H	11	-0.041	1.874	-	9	-0.006	0.769	-
I	10	-0.22	1.997	-	8	-0.83	3.696	0.010
J	14	-0.68	1.942	-	12	-1.51	3.70	0.005
H - I	7	-0.18	1.50	-	5	-0.177	2.529	0.05
J	11	-0.643	1.429	-	9	-1.502	2.815	0.025
I - J	10	0.46	0.885	-	8	-1.325	2.103	-

d.f. = Degree of Freedom

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

t = The calculated t value

P = Probability level of significance.

Appendix C12: Comparison of Groups of Stands by soil  
organic matter (using t-test)

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B	16	-0.9	1.552	-	16	-0.12	0.500	0.01
C	10	-3.59	4.918	0.001	10	-2.11	3.200	0.01
D	19	-2.11	1.760	-	9	-0.27	0.818	-
E	17	-0.07	0.209	-	17	0.29	7.381	-
F	14	0.47	2.021	-	14	0.61	3.223	0.005
G	12	-0.2	2.460	0.050	11	0.58	3.889	0.005
H	9	0.90	2.903	0.025	8	0.58	2.417	0.05
I	8	-0.59	1.844	-	7	0.59	2.950	0.025
J	12	1.21	4.3421	0.001	11	0.93	6.643	0.001
B - C	15	-2.69	3.682	0.005	16	-1.99	4.061	0.001
D	15	-1.14	1.14	-	15	-0.15	0.484	-
E	23	0.9	2.25	0.05	23	0.41	2.05	-
F	20	1.44	3.535	0.005	20	0.73	3.668	0.005
G	18	0.77	1.013	-	17	0.7	3.330	0.005
H	15	1.87	2.968	0.001	14	0.7	2.414	0.05
I	14	1.56	2.438	0.05	13	0.71	2.90	0.025
J	18	2.18	4.75	0.01	17	1.05	5.00	0.001
C - D	9	1.55	1.092	-	9	1.84	2.390	0.05
E	17	3.59	7.039	0.001	17	2.40	5.106	0.001
F	14	4.13	7.441	0.001	14	2.72	5.389	0.001
G	12	3.46	3.456	0.005	11	2.69	4.528	0.001
H	9	4.56	5.70	0.001	8	2.69	3.28	0.025
I	8	4.25	1.687	-	7	2.71	2.372	0.025
J	12	4.87	7.83	0.001	11	3.04	5.153	0.001

Appendix C 12 continued

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
D - E	16	2.04	2.520	0.025	16	0.56	1.931	-
F	13	2.58	2.835	0.025	13	0.88	3.71	0.005
G	11	1.91	1.423	-	9	0.85	3.157	0.025
H	8	3.01	2.98	0.025	7	0.94	2.101	-
I	7	2.07	1.389	-	6	0.86	1.955	-
J	11	3.32	3.225	0.01	10	1.20	4.286	0.005
E - F	21	0.54	3.105	0.01	21	0.32	1.864	-
G	19	-0.13	0.227	-	18	0.29	1.595 $\frac{1}{2}$	-
H	16	0.97	3.345	0.005	15	0.29	1.115	-
I	15	-0.83	2.677	0.025	14	0.3	1.111	-
J	19	0.21	0.840	-	18	7.20	4.286	0.005
F - G	16	-0.67	1.094	-	15	-0.03	0.219	-
H	13	0.43	1.596	-	12	-0.03	0.144	-
I	12	-0.12	0.423	-	11	-0.02	0.099	-
J	16	0.74	3.083	0.01	15	0.32	2.535	0.025
G - H	11	1.1	1.201	-	9	0	0	-
I	7	0.31	0.816	-	5	0.01	0.04	-
J	10	0.62	18.24	-	8	0.34	4.196	0.005
H - I	7	-0.31	0.816	-	5	0.01	0.04	-
J	11	0.31	0.969	-	9	0.35	2.188	-
I - J	10	0.62	1.824	-	8	0.34 $\frac{1}{2}$	4.196	0.005

d.f. = Degree of freedom

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

t = The calculated t valued

P = Probability level of significance.

Appendix C13: Comparison of Groups of stands by soil potassium  
(using t-test)

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B	16	0.02	1.333	-	16	0.02	1.000	-
C	10	-0.06	1.818	-	10	-0.02	-0.500	-
D	9	0.02	0.889	-	9	0.05	1.667	-
E	17	0.02	0.667	-	17	-0.03	-2.143	0.05
F	14	-0.07	1.728	-	14	-0.02	-2.599	-
G	12	-0.03	0.505	-	11	0	0	-
H	9	-0.16	2.286	0.05	8	0.11	-2.200	-
I	8	-0.76	3.167	0.025	7	1.03	-3.815	-
J	12	-1.06	3.313	0.01	11	1.13	-2.628	0.025
B - C	16	-0.08	4.000	0.005	16	0.04	-1.818	-
D	15	-0.0	0.000	-	15	0.03	3.000	-
E	23	-0.02	1.539	-	23	0.05	-0.625	-
F	20	-0.47	5.553	0.001	20	0.04	-0.625	-
G	18	-0.07	1.891	-	17	0.02	-1.019	-
H	15	-0.20	5.000	0.001	14	0.13	-4.333	0.001
I	14	-0.80	5.714	0.001	13	1.05	-7.000	0.001
J	18	1.10	5.000	0.001	17	1.15	-3.835	0.005
C - D	9	0.08	2.166	-	9	0.07	2.000	-
E	17	0.06	2.400	0.050	17	0.01	-0.083	-
F	14	0.03	-0.816	-	14	0.00	0.000	-
G	12	0.01	2.178	-	11	0.02	0.517	-
H	9	0.12	-1.818	-	8	0.09	-1.579	-
I	8	0.72	-3.00	0.025	7	1.01	-4.390	0.005
J	12	1.02	-3.188	0.01	11	1.11	-2.581	0.05

Appendix C-13 continued

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
D - E	16	0.02	-1.000	-	16	0.13	-0.615	0.001
F	13	0.11	-11.000	0.001	13	0.07	-5.131	0.001
G	11	0.07	-1.817	-	9	0.05	-1.785	-
H	8	0.20	-3.051	0.025	7	0.16	-3.154	0.010
I	7	0.80	-3.077	0.025	6	1.08	-4.320	0.005
J	11	1.10	-3.056	0.025	10	1.18	-2.458	0.05
E - F	21	-0.009	3.876	0.001	21	0.01	0.11	-
G	19	-0.05	1.374	-	18	0.03	0.273	-
H	16	-0.182	4.333	0.001	15	-0.08	5.333	0.001
I	15	-0.80	3.077	0.025	6	-1.08	4.545	0.001
J	19	-1.18	5.619	0.001	18	-1.10	3.667	0.005
F - G	16	0.04	8.879	-	15	0.02	0.895	-
H	13	-0.09	1.669	-	12	-0.09	2.636	0.025
I	12	-0.69	0.0280	-	11	-1.01	5.960	0.001
J	16	-0.99	4.125	0.001	15	-1.11	3.541	0.005
G - H	11	-0.13	1.759	-	9	-0.11	2.194	-
I	10	-0.73	2.906	0.005	8	-1.03	4.902	0.001
J	14	-1.03	3.685	0.005	12	-1.13	2.832	0.025
H - I	7	-0.63	2.143	-	5	-0.92	3.172	0.025
J	11	-0.90	2.500	0.05	9	-1.02	1.889	-
I - J	10	-0.30	0.682	-	8	-0.10	0.152	-

d.f. = Degree of freedom

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

t = The calculated t value

P = Probability level of significance

Appendix C14: Comparison of groups of stands by soil calcium (using t-test)

Groups Compared		d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B		16	-2.76	0.767		16	3.33	0.865	
	C	10	-4.25	1.832	-	10	-0.75	0.144	-
	D	9	-3.03	0.625	-	9	-1.35	0.195	-
	E	17	2.48	1.240	-	17	5.86	1.196	-
	F	14	3.89	1.498	-	14	7.76	1.920	-
	G	12	-4.71	0.958	-	11	0.44	0.77	-
	H	9	-1.88	0.358	-	8	-6.6	0.723	-
	I	8	-20.96	3.756	0.01	7	-25.82	1.501	-
	J	12	-17.39	3.208	0.01	11	-20.88	3.769	0.005
B - C		16	-1.49	0.416	-	16	-4.08	2.217	0.05
	D	15	-0.27	0.059	-	15	-1.98	0.606	-
	E	23	5.24	2.120	0.05	23	2.53	1.807	-
	F	20	6.65	2.552	0.025	20	4.43	0.43	-
	G	18	-1.95	0.449	-	17	-2.89	1.062	-
	H	15	0.88	0.183	-	14	-9.93	2.043	-
	I	14	-18.2	3.889	0.005	13	-29.15	3.189	0.01
	J	18	-14.69	3.222	0.005	17	-24.21	9.136	0.001
C - D		9	1.22	0.269	-	9	2.1	0.495	-
	E	17	6.73	3.963	0.001	17	6.61	4.407	0.001
	F	14	8.14	3.519	0.005	14	8.51	5.743	0.001
	G	12	-0.46	0.097	-	11	1.19	0.348	-
	H	9	2.37	0.478	-	8	-5.58	0.874	-
	I	8	-16.71	3.201	0.025	7	-25.07	1.864	-
	J	12	-13.14	2.500	0.050	11	-20.13	6.119	0.001

Appendix C14 continued

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
D - E	16	5.51	18.68	-	16	4.51	1.539	-
F	13	6.92	1.896	-	13	6.41	1.94	-
G	11	-1.68	0.280	-	9	-0.91	0.185	-
H	8	1.15	0.174	-	7	-7.95	0.831	-
I	7	-17.93	2.487	0.05	6	-27.17	1.702	-
J	11	-14.36	2.209	0.005	10	-22.23	4.411	0.005
E - F	21	1.41	0.929	-	21	1.90	1.557	-
G	19	-7.19	0.297	-	18	-5.42	2.240	0.05
H	16	-4.36	1.350	-	15	-12.46	2.798	0.025
I	15	-23.44	7.018	0.001	14	-31.68	3.645	0.005
J	19	-19.87	5.710	0.001	18	-26.74	11.379	0.001
F - G	16	-8.6	2.318	0.05	15	-7.32	2.748	0.025
H	13	-5.77	1.461	-	12	-14.36	2.841	0.025
I	12	-24.85	4.720	0.001	11	-33.58	3.344	0.01
J	16	-21.78	5.325	0.001	15	-28.64	11.485	0.001
G - H	11	2.83	0.454	-	9	-7.04	0.978	-
I	10	-16.25	2.169	-	8	-26.26	2.019	-
J	14	-12.68	2.02	-	12	-21.32	5.340	0.001
H - I	7	-19.08	2.497	0.05	5	-19.23	0.998	-
J	11	-21.51	3.201	0.01	9	-14.28	2.008	-
I - J	10	3.57	0.486	-	8	4.94	0.383	-

d.f. = Degree of freedom

$X_1 - X_2$  = The difference between the means of the means of the groups compared

t = The calculated t value

P = Probability level of significance

Appendix C 15: Comparison of groups of stand by soil magnesium  
(using t-test)

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	I	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B	16	-0.34	0.486	-	16	-1.34	2.138	0.05
C	10	-1.03	1.451	-	10	-1.75	2.652	0.025
D	9	0.29	0.500	-	9	1.15	2.130	-
E	17	-1.26	2.066	-	17	-0.059	0.844	-
F	14	0.80	3.208	0.01	14	1.24	3.013	0.01
G	12	0.57	1.056	-	11	1.38	3.144	0.01
H	9	0.97	4.217	0.005	8	1.58	2.873	0.025
I	8	0.07	0.111	-	7	-2.06	1.084	-
J	12	0.85	2.656	0.025	11	1.11	1.147	-
B - C	16	-0.69	1.211	-	16	-0.36	0.522	-
D	15	1.31	1.985	-	15	2.54	3.791	0.005
E	23	0.34	0.680	-	23	0.76	1.333	-
F	20	2.4	6.463	0.001	20	2.63	5.242	0.001
G	18	2.17	3.786	0.005	17	2.77	1.22	-
H	15	2.57	4.673	0.001	14	2.97	4.014	0.005
I	14	1.67	2.530	0.025	13	-0.67	0.508	-
J	18	2.45	5.104	0.001	17	2.5	4.032	0.001
C - D	9	2.00	2.857	0.025	9	2.90	4.462	0.005
E	17	1.03	1.583	-	17	1.12	1.600	-
F	14	3.09	8.432	0.001	14	2.99	6.218	0.001
G	12	2.86	4.65	0.001	11	3.13	5.874	0.001
F	9	3.26	7.409	0.001	8	3.33	4.897	0.005
I	8	2.36	3.0648	0.025	7	-0.31	0.181	-
J	12	3.14	3.877	0.005	11	2.86	4.469	0.005

Appendix C 15 continued

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
D - E	16	-0.97	1.311	-	16	-1.74	2.522	0.025
F	13	1.09	2.370	0.05	13	0.09	0.239	-
G	11	0.86	1.046	-	9	0.23	0.639	-
H	8	1.26	2.125	-	7	0.43	0.901	-
I	7	-0.36	0.387	-	6	-3.21	1.814	-
J	11	1.14	2.111	-	10	-0.04	0.074	-
E - F	19	1.83	2.998	0.01	18	1.97	3.434	-
G	16	0.23	0.548	-	15	0.14	0.462	-
H	16	2.23	3.400	-	15	2.17	2.893	-
I	12	0.75	0.460	-	11	-3.30	2.733	0.025
J	19	2.11	3.907	0.001	18	1.7	2.742	0.025
F - G	16	0.23	0.548	-	15	0.14	0.462	-
H	13	0.17	0.734	-	12	0.34	0.920	-
I	12	-0.75	0.460	-	11	-3.30	2.733	0.025
J	16	0.06	0.231	-	15	-0.13	0.331	-
G - H	11	0.4	0.703	-	9	0.2	0.590	-
I	10	-0.5	0.606	-	8	-3.44	2.390	-
J	14	0.28	0.567	-	12	-0.27	0.617	-
H - I	7	-0.9	1.364	-	5	-3.64	1.848	-
J	11	-6.12	0.387	-	9	-0.47	0.839	-
I - J	10	0.78	1.322	-	8	3.17	2.072	-

d.f. = Degree of freedom

$X_1 - X_2$  = The difference between the means of the groups compared

t = The calculated t value

p = Probability level of significance

Appendix C 16: Comparison of groups of stands by soil sodium  
(using t-test)

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B	16	0.04	9.889	0.001	16	0.26	1.733	-
C	10	0.07	2.222	0.05	10	0.31	1.722	-
D	9	0.13	1.625	-	9	0.34	1.700	-
E	17	0.13	2.708	0.025	17	0.36	3.000	0.01
F	14	0.13	2.181	0.05	14	0.36	2.590	0.025
G	12	0.09	1.342	-	11	0.31	1.809	-
H	9	0.09	1.125	-	8	0.28	1.217	-
I	8	-0.11	0.846	-	7	-3.77	1.261	-
J	12	-0.97	1.940	-	11	-1.98	1.505	-
B - C	16	0.03	1.500	-	16	0.05	1.625	-
D	15	0.09	3.600	0.005	15	0.08	0.889	-
E	23	0.09	4.500	0.001	23	0.10	1.667	-
F	20	0.09	2.846	0.01	20	0.10	1.527	-
G	18	0.05	3.229	0.005	17	0.05	0.626	-
H	15	0.05	4.000	0.005	14	0.02	2.00	-
I	14	-0.15	2.500	0.025	13	-4.03	1.966	-
J	18	-1.01	2.149	0.05	17	-2.24	4.392	0.001
C - D	9	0.06	2.000	-	9	0.03	1.500	-
E	17	0.06	2.000	-	17	0.05	2.500	0.025
F	14	0.05	2.437	0.05	14	0.05	3.607	0.005
G	12	0.02	0.547	-	11	0.00	0.00	-
H	9	0.02	0.667	-	8	0.03	0.833	-
I	8	-0.18	2.000	-	7	-4.08	1.619	-
J	12	-1.04	2.122	0.050	11	-2.29	3.095	0.025

Appendix C 16 continued

Groups Compared	Surface				Average			
	d.f.	$X_1 - X_2$	T	P	d.f.	$X_1 - X_2$	T	P
D - E	16	0.00	-	-	16	0.02	1.333	-
F	13	0.00	-	-	13	0.02	0.652	-
G	11	-0.04	1.223	-	9	-0.03	0.915	-
H	8	-0.04	2.511	0.050	7	-0.06	1.578	-
I	7	-0.24	2.449	0.050	66	-4.11	1.200	-
J	11	-1.1	2.037	-	10	-2.32	2.864	0.025
E - F	21	0.00	1.343	-	21	0.00	-	-
G	19	-0.04	1.942	-	18	-0.05	1.785	-
H	16	-0.04	1.333	-	15	-0.08	4.00	-
I	12	-0.24	3.485	0.005	11	-4.13	2.206	0.050
J	19	-1.13	3.727	0.005	18	-2.34	4.875	0.001
F - G	16	-0.04	1.331	-	15	-0.05	2.265	0.05
H	13	-0.04	2.582	0.025	12	-0.98	3.779	0.005
I	12	-0.24	3.485	0.005	11	-4.13	2.565	0.025
J	16	-1.10	2.941	0.01	15	-2.34	4.380	0.001
G - H	11	0.00	0.00	-	9	-0.003	0.673	-
I	10	0.00	2.225	0.05	8	-4.08	1.778	-
J	14	1.06	2.503	0.025	12	-2.29	4.955	0.001
H - I	7	-0.20	2.020	-	5	-4.05	1.266	-
J	11	-1.06	1.963	-	9	-2.26	2.457	0.050
I - J	10	-0.78	1.322	-	8	1.74	0.710	-

d.f. = Degree of freedom

$X_1 - X_2$  = The difference between the means of the groups compared

t = The calculated t value

p = Probability level of significance

Appendix C 17: Comparison of stand groups by soil manganese  
(using t-test)

Groups Compared	Surface				Average			
	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P	d.f.	$\bar{X}_1 - \bar{X}_2$	T	P
A - B	16	0.006	1.000	-	16	0.21	30.000	0.001
C	10	-0.07	2.692	0.025	10	-0.032	1.333	-
D	9	0.006	0.100	-	9	-0.01	1.000	-
E	17	0.007	1.167	-	17	0.01	1.667	-
F	14	-0.004	0.008	-	14	0.02	0.278	-
G	12	0.005	0.032	-	11	0.012	1.88	-
H	9	-0.003	3.000	0.025	8	0.00	0.00	-
I	8	-0.012	0.800	-	7	0.015	1.154	-
J	12	0.017	0.895	-	11	0.018	2.000	-
B - C	16	-0.064	3.368	0.005	16	-0.596	3.973	0.005
D	15	0.000	0.000	-	15	-0.22	55.000	0.001
E	23	0.006	1.200	-	23	0.06	13.333	0.001
F	29	-0.005	0.015	-	20	-0.004	1.245	-
G	18	0.320	4.814	0.001	17	0.06	1.630	-
H	15	-0.004	0.571	-	14	-0.21	42.000	0.001
I	14	-0.013	1.300	-	13	0.009	1.500	-
J	18	0.016	1.143	-	17	0.012	3.000	0.01
C - D	9	0.064	2.207	-	9	0.04	1.667	-
E	17	0.07	3.389	0.005	17	0.042	4.200	0.001
F	14	0.059	0.113	-	14	0.034	2.125	-
G	12	0.068	0.747	-	11	0.044	2.193	-
H	9	0.060	2.069	-	8	0.032	1.185	-
I	8	0.051	1.457	-	7	0.047	1.469	-
J	12	0.080	2.759	0.025	11	0.05	2.500	0.05

Appendix C 17 continued

Groups Compared	Surface				Average			
	d. f.	$\bar{X}_1 - \bar{X}_2$	T	P	d. f.	$\bar{X}_1 - \bar{X}_2$	T	P
D - E	16	0.006	1.000	-	16	0.00	0.00	-
F	13	-0.005	0.009	-	13	0.008	1.412	-
G	11	0.32	0.499	-	9	0.002	0.726	-
H	8	-0.004	0.452	-	7	0.04	1.492	-
I	7	-0.013	0.867	-	6	0.005	1.250	-
J	11	0.016	2.000	-	10	0.008	3.478	0.01
E - F	21	-0.011	0.032	-	21	-0.008	4.259	0.001
G	19	-0.002	0.380	-	18	0.002	0.952	-
H	16	-0.01	0.769	-	15	-0.001	3.333	0.005
I	15	-0.037	4.111	0.001	14	0.005	1.667	-
J	19	-0.008	1.538	-	18	0.008	2.000	-
F - G	16	0.09	0.020	-	15	0.01	4.563	0.001
H	13	0.001	0.02	-	12	-0.002	0.536	-
I	12	-0.009	0.004	-	11	0.0013	3.904	0.005
J	16	0.021	0.948	-	15	0.016	8.887	0.001
G - H	11	-0.008	0.992	-	9	-0.12	2.789	0.025
I	10	-0.017	1.218	-	8	00.003	0.829	-
J	14	0.012	1.697	-	12	0.006	1.790	-
H - I	7	-0.007	0.600	-	5	0.075	2.143	-
J	11	0.02	2.500	0.05	9	0.018	0.033	-
I - J	10	0.029	2.477	0.05	8	0.003	1.071	-

d.f. = Degree of freedom

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

t = The calculated t value

p = Probability level of significance

Appendix D1

Ordination Scores of the Stands from the Eastern  
Escapment of Ertrea

Stand No.	DCA Scores		RA Scores	
	Axis 1	Axis 2	Axis 1	Axis 2
1	52	159	-211	338
2	6	140	-225	416
3	23	161	-221	370
4	0	145	-232	386
5	17	166	-223	376
6	34	195	-221	340
7	28	176	-222	325
8	11	182	-228	401
9	84	172	-206	108
10	69	117	-209	127
11	70	150	-208	151
12	65	64	-211	100
13	92	133	-202	68
14	90	147	-202	98
15	102	118	-200	30
16	120	127	-193	41
17	137	161	-187	11
18	139	89	-187	-13
19	163	81	-179	-41
20	149	92	-167	-11
21	1-4	114	-185	-27
22	137	115	-186	-13
23	144	137	-186	-18
24	144	146	-184	4
25	140	142	-185	-12

Appendix D1 continued.

Stand No.	DCA Scores		AR Scores	
	Axis 1	Axis 2	Axis 1	Axis 2
26	172	67	-176	-55
27	168	51	-165	-50
28	175	50	-168	-66
29	183	90	-157	-57
30	206	53	-149	-84
31	174	80	-165	-45
32	176	72	-162	-46
33	186	59	-156	-56
34	248	16	-110	-79
35	236	0	-126	-90
36	266	8	- 93	-87
37	258	24	-106	-100
38	236	64	-129	-93
39	205	157	-149	-37
40	266	65	- 98	-97
41	280	61	- 81	-87
42	260	58	-116	-108
43	283	20	- 96	-120
44	299	69	- 76	-121
45	262	52	-114	-107
46	283	65	- 91	-110
47	239	48	-126	- 75
48	244	250	- 76	23
49	282	254	- 43	- 22
50	319	213	- 4	- 29
51	295	195	- 42	- 48
52	293	36	- 64	- 94
53	301	70	- 57	-111

Appendix D1 continued.

Stand No.	DCA Scores		AP Scores	
	Axis 1	Axis 2	Axis 1	Axis 2
54	549	98	320	13
55	52	131	303	8
56	558	104	336	12
57	527	108	298	- 2
58	547	96	232	- 3
59	525	137	288	- 3
60	591	152	381	21
61	563	153	350	14
62	584	106	362	22
63	582	85	367	18
64	611	18	389	53
65	629	35	418	36
66	600	85	381	30
67	591	96	376	21
68	602	48	386	24
69	607	94	393	26
70	569	169	355	11
71	558	158	334	6
72	598	103	381	24
73	602	111	392	25
74	586	141	370	20
75	598	122	389	26
76	572	146	366	14
77	570	159	356	12

DCA = Detrended correspondence analysis.

RA = Reciprocal averaging.

Appendix D2

Ordination Scores of Group 2 Stands

Stand No.	DCA Scores (Standardize over 0-100 Range)		RA Scores (Standardize over 0-100)	
	Axis 1	Axis 2	Axis 1	Axis 2
1	91.2	41.5	52.9	70.6
2	94.3	45.0	56.8	92.9
3	98.3	38.1	61.9	99.2
4	99.5	38.1	96.7	100.0
5	96.0	41.9	100.0	91.0
6	92.6	46.2	92.2	72.9
7	92.4	28.5	52.7	74.5
8	100.0	28.1	62.4	100.0
9	67.6	40.0	31.3	14.9
10	68.1	27.3	31.3	19.2
11	67.9	40.4	32.2	24.7
12	63.6	28.1	27.6	25.5
13	59.3	35.4	24.5	5.1
14	62.1	44.2	26.9	10.6
15	55.0	41.5	22.1	0.0
16	52.1	33.5	21.1	9.4
17	47.1	42.7	17.8	9.0
18	36.0	25.0	13.0	17.3
19	34.3	16.1	12.6	22.4
20	38.1	19.6	14.3	18.4
21	38.1	23.1	14.2	17.6
22	42.4	23.8	16.0	16.0
23	40.7	30.8	15.3	9.8
24	41.2	35.4	16.1	22.7
25	38.1	33.8	14.2	19.6

Appendix D2 continued.

Stand No.	DCA Scores (Standardize over 0-100 Range)		RA Scores (Standardize over 0-100 Range)	
	Axis 1	Axis 2	Axis 1	Axis 2
26	29.5	16.5	11.1	27.5
27	33.3	11.2	12.5	22.4
28	25.7	3.1	9.6	31.4
29	25.7	19.2	9.6	32.9
30	20.5	5.8	7.2	36.9
31	31.4	11.2	11.5	25.1
32	30.2	20.8	11.7	34.5
33	30.5	21.9	11.9	36.1
34	17.6	2.3	6.8	63.9
35	9.8	1.9	3.3	65.5
36	14.0	0.0	5.2	61.6
37	12.9	10.4	4.6	62.0
38	18.1	30.4	6.5	56.5
39	32.6	51.2	12.4	38.4
40	5.5	40.8	2.2	83.1
41	9.3	54.2	3.4	13.7
42	6.2	47.7	2.3	83.1
43	1.0	35.0	0.4	89.0
44	0.0	60.0	0.0	97.3
45	7.1	45.4	2.7	83.1
46	4.5	46.2	1.5	85.1
47	11.9	33.1	4.2	66.7
48	40.5	71.2	15.8	32.2
49	23.1	100.0	8.8	72.2
50	21.9	93.5	8.6	66.7
51	15.5	96.9	6.5	82.4
52	6.2	58.8	3.1	93.7
53	3.3	51.5	1.3	92.5

DCA = Detrended correspondence analysis

RA = Reciprocal averaging