

A STUDY
OF ALTITUDINAL PLANT ZONATION
ON THE WESTERN SLOPES OF MOUNT CHILALO, ARSI

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A STUDY OF
ALTITUDINAL PLANT ZONATION ON THE WESTERN SLOPES OF
MOUNT CHILALO, ARSI

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Kebrom Tekle

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ABSTRACT

A Study of Altitudinal Plant Zonation on the Western Slopes of Mount Chilalo, Arsi

By
Kebrom Tekle

That most forests in Ethiopia are unwisely exploited, leading to frightening conditions, has been pointed out by many researchers. To ameliorate the situation proper conservation policies based on a good knowledge of plant species and their environment is very important. It is with this belief that this study on the Western Slopes of Mount Chilalo was attempted.

To carry on the suggested study, 60 stands were laid along two transects. The stands were selected by systematic sampling. Altitude and slope of every stand were recorded. All new plant species in the stands were collected and later on identified in the National Herbarium of Addis Ababa University. Those species which occurred repeatedly were recorded. Soil samples were taken from 5 levels (0-10, 20-30, 40-50, 60-70, 80-90cms) of every stand and several chemical and physical properties (pH, conductivity, soil color, texture, the availability of Ca, Mg, K, Na, Mn) were determined. A computer, in the Ethiopian Transport and Construction Authority, was used to classify the stands into groups by applying corrected chi square index. The technique chosen for classification was Association Analysis.

The 60 stands were divided into 14 groups out of which 5 were rejected because they consisted only of one stand each. Mean values and t-tests were computed to compare the remaining 9 groups and clear

ABSTRACT (Cont'd)

differences especially between the stands with and without Erica arborea, were seen in most of the variables considered. Based on the findings the vegetation on the Western Slopes was divided into four categories with more problems in categories 2 and 4 which were affected by burning and defforestation respectively. Before the problems extend to categories 1 and 3, it is suggested that ways and means should be sought to decrease defforestation (in category 4) and substitute it by reafforestation programme; and minimize animal rearing (in category 2) which might decrease the fire hazards in the area dominated by Erica arborea.

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CHAPTER 1

INTRODUCTION

1.1. The Problem

The unwise exploitation of forest resources for fuel, burning for more pasture lands and clearing of forests for additional areas of cultivation have contributed a lot to the reduction of forests and destruction of vegetation in the country at large and in the Chilalo Mountain in particular. If this continues, the Ethiopian forest resources which, according to Russ (1944 as quoted by Hailu 1982 p.1.), were the greatest in East Africa and contained the largest coniferous trees in the continent, will disappear in the near future. The wet and dry evergreen montane forests which used to cover a large part of the Ethiopian Plateau has now dwindled away that only four percent of the relic forest is remaining as patches in inaccessible areas (Brown, 1973; Eckholm, 1976; as quoted by Zerihun, 1980 p.5).

Regarding the fast depletion of our vegetation (especially forest resources), Hedberg (1979, as quoted by Hailu 1982, p.2) points out that with the present trend of destructive methods of exploiting the remaining sparse forest resources and their conversion into agricultural land, there will be little hope of having any forest worth mentioning after a few years.

1.2. Objectives of the Study

To reverse the problems mentioned earlier, proper management and conservation policies are not only necessary but indispensable. One of the inputs needed for the implementation of these policies is a knowledge of the plant communities and their environment. The objective of this study is to collect information on the interaction

between the plant species and their environmental complex and ultimately describe the spatial distribution of the vegetation on the Western Slopes of Mount Chilalo, the study area, in relation to several environmental factors namely altitude, slope, soil pH, conductivity, texture, soil color and the availability of sodium, potassium, magnesium, manganese and calcium.

1.3. Justification and Rationale

The Chilalo Mountain, important for timber resources and the home of one of the rare animals, Nyala, is one of the threatened forests of Ethiopia. Large areas above the tree line have experienced fire hazards several times. Moreover, it is not unusual to see people cutting down big trees for fuel to be sold at Assela, the nearby town. One can also observe areas, at high altitude and adjacent to the forest remnants, being allotted for crop production. It is with the belief that this unfortunate development should be arrested before the ecosystem is very much disrupted and more problems appear on the scene that this study is carried on.

The area was selected for study for two reasons:

- a) familiarity of the writer with the area
- b) there were friends (employees in Arsi Rural Development Unit - ARDU) who were ready to render unreserved help regarding the field work.

1.4. Scope of the Study

As has been stated earlier, the study is focussed on the Western Slopes of Mount Chilalo. This is because Mount Chilalo is a very extensive area and it is beyond the scope of this paper to cover the whole area. Moreover, except for some slight differences,

the study may also give a good idea about the vegetation in the mountain as a whole.

1.5. Methods of Data Collection and Analysis

1.5.1. Data Collection

For the purpose of this study, systematic sampling was used to select 60 stands (20X20m) along two transects on the Western Slopes of Mount Chilalo. The altitudinal variation of one stand from the other is 45 meters.

All new plant species in the 60 stands were collected in polythelene bags and later pressed for identification. Plant species which occurred repeatedly were, on being encountered again, only recorded, continuing to collect them being unnecessary.

As to the environmental factors, altitude and slope for each stand were recorded using an Everest Altimeter and a Suunto Clinometer respectively. Except where augering was impossible due to shallow bedrock, soil samples were collected in polythelene bags from 5 levels (0-10, 20-30, 40-50, 60-70, 80-90 cms) of every stand.

1.5.2. Data Analysis

The plant species collected from the field were taken to the National Herbarium of Addis Ababa University and were identified.

The soil samples collected from the stands were air dried, ground by mortar and pestle and sieved through a 2mm sieve. Then the following physical and chemical properties were determined in the soil laboratory (Biology Department, AAU):

a) Soil pH was measured in 1:1 ratio by adding 20ml of distilled water to a 20 gm of air dry soil passed through 2mm sieve. It was allowed to stand for 30 minutes after which reading was made using

a Beckman Chem. Mate pH Meter, (Jou, 1978).

b) Conductivity measurement followed the same procedure as soil pH in mixing the soil and the distilled water. After the mixture of soil and dist. water was allowed to stand for 30 minutes, conductivity was measured using a Phillip Harris Conductivity Bridge.

c) Soil Color was determined by comparing the color of the soil samples with the Munsell Color Chart.

d) Texture was determined by the Hydrometer Method of mechanical analysis. Fifty cc of 5% Sodium Hexametaphosphate along with 100cc of distilled water was added to a 51.0gm of air dry soil in a cup and allowed to rest for 30 minutes. Then it was stirred for 15 minutes with a mechanical stirrer. The suspension was then transferred from the cup to a glass cylinder of 1000cc and temperature and hydrometer readings were recorded during the first forty seconds and after 3 hours using a thermometer and a hydrometer respectively, (Jou, 1978).

e) Cations - For the determination of exchangeable bases (Ca, Mg, K, Na and Mn) 1N concentration of ammonium acetate solution was used. Thirty ml of ammonium acetate was added to 5 gms of a soil sample and shaken with a mechanical shaker for two hours. It was then centrifuged (2000 r.p.m.) for 10 minutes and the clear supernatant was transferred into a 100 ml volumetric flask. Another 30 ml of ammonium acetate was added shaken for 30 minutes and centrifuged. The supernatant was transferred into the same volumetric flask. Step two was repeated. The supernatant was then diluted to 100 ml with ammonium acetate. Finally to determine the amount of Ca, Mg, and Mn, a Varian Tectron AA6 Atomic Absorption Spectrophotometer was used.

The amount of Na and K was determined using a Buckman Kline Flame Photometer, (Jou, 1978).

1.5.3. Data Summarization

After the vegetation and soil analysis data were compiled, the stands in the study area had to be divided into groups (based on the presence and absence of species) to see the possible plant-environment relationships. The technique applied, as will be discussed in the next chapter, was association analysis using a corrected chi square index. The raw data on the presence and absence of plant species in the respective stands was bulky that a computer, (NCR Criterion V8555) in the Ethiopian Transport and Construction Authority, was used for the computation. Mean values and t-tests were computed to see the contrasts among the groups. Based on these findings (and also the observation in the field) recommendations are suggested especially for those areas where the problems seem to be acute.

CHAPTER 2

DESCRIPTION OF THE STUDY AREA AND

REVIEW OF RELATED LITERATURE

2.1. Description of the Study Area

2.1.1. Location

The study area, which is part of the Chilalo Mountain Ranges of the South Eastern Highlands, roughly falls between 7°53'N to 7°59'N and 39°08'E to 39°15'E.

2.1.2. Landform and Geology

The study area rises gently from the flat lying highland (about 2350 m.a.s.l.) to an elevation of about 4000 m.a.s.l. at its summit. It stands east of the town of Assela prominently overlooking the Rift towards the west and it is topped by a caldera, which according to Di Paola (1972, p.25) is about 6 kms in diameter.

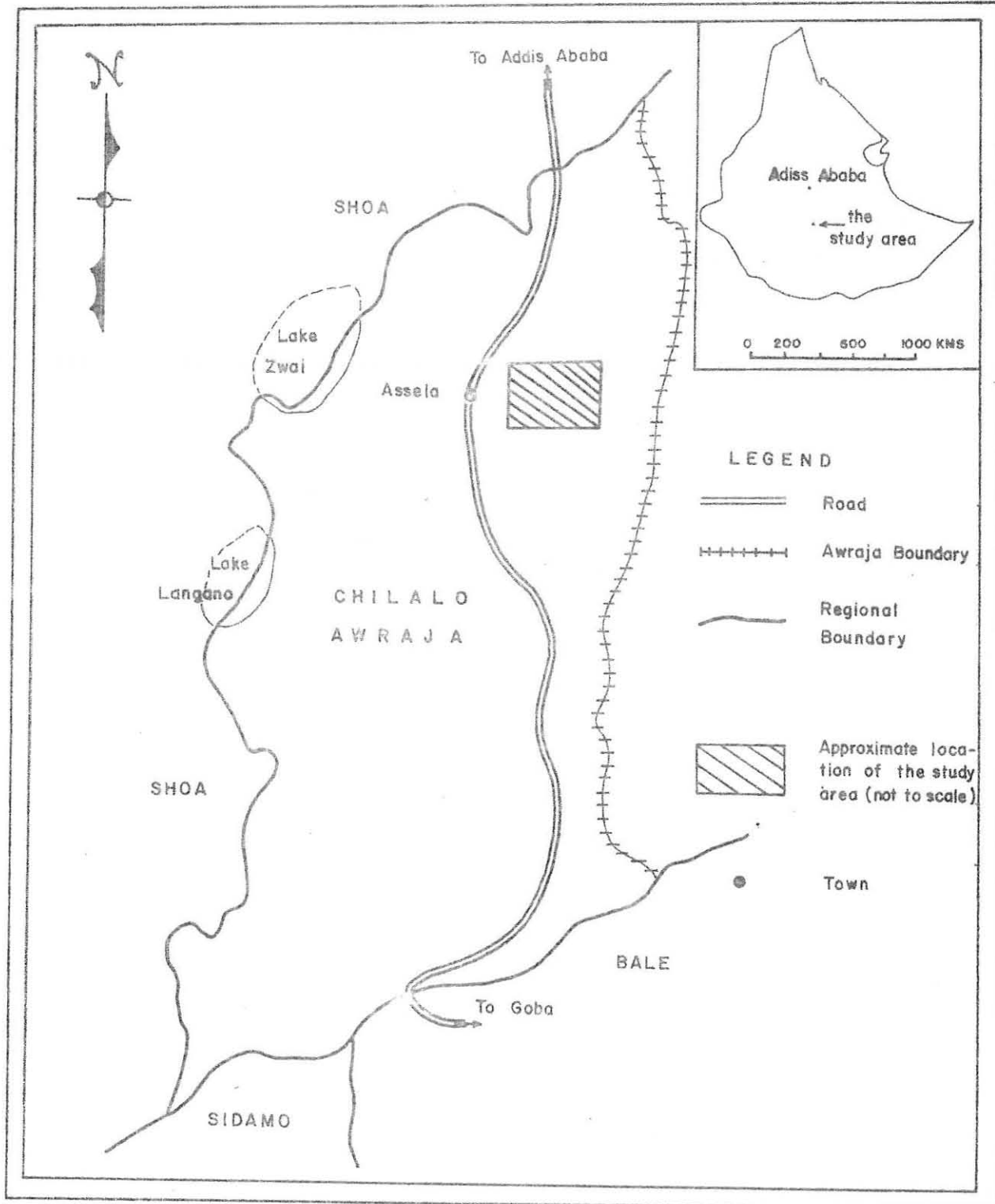
Mount Chilalo (the area under study included) is characterized by radial drainage. Innumerable streams emanate from the upper part of the mountain (at about 3700 m.a.s.l.) and flow to the gentler slopes and join to form bigger streams important among which are Konicha, Anko, Dosha, Kombolcia and Milko.

The geomorphic features in the Chilalo Mountain are very young due to its short geological history, (Mohr, 1967). The products of Chilalo Mountain include basalts and trachybasalts and are the oldest rocks in the area, (Bekele, 1982 p.22).

The Chilalo Basalt, which is exposed at the base of the escarpment, attains a maximum thickness of 15m. Several Valley sides and floors on the Western side of Mount Chilalo indicate the

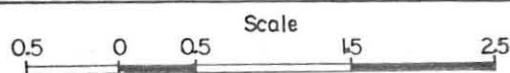
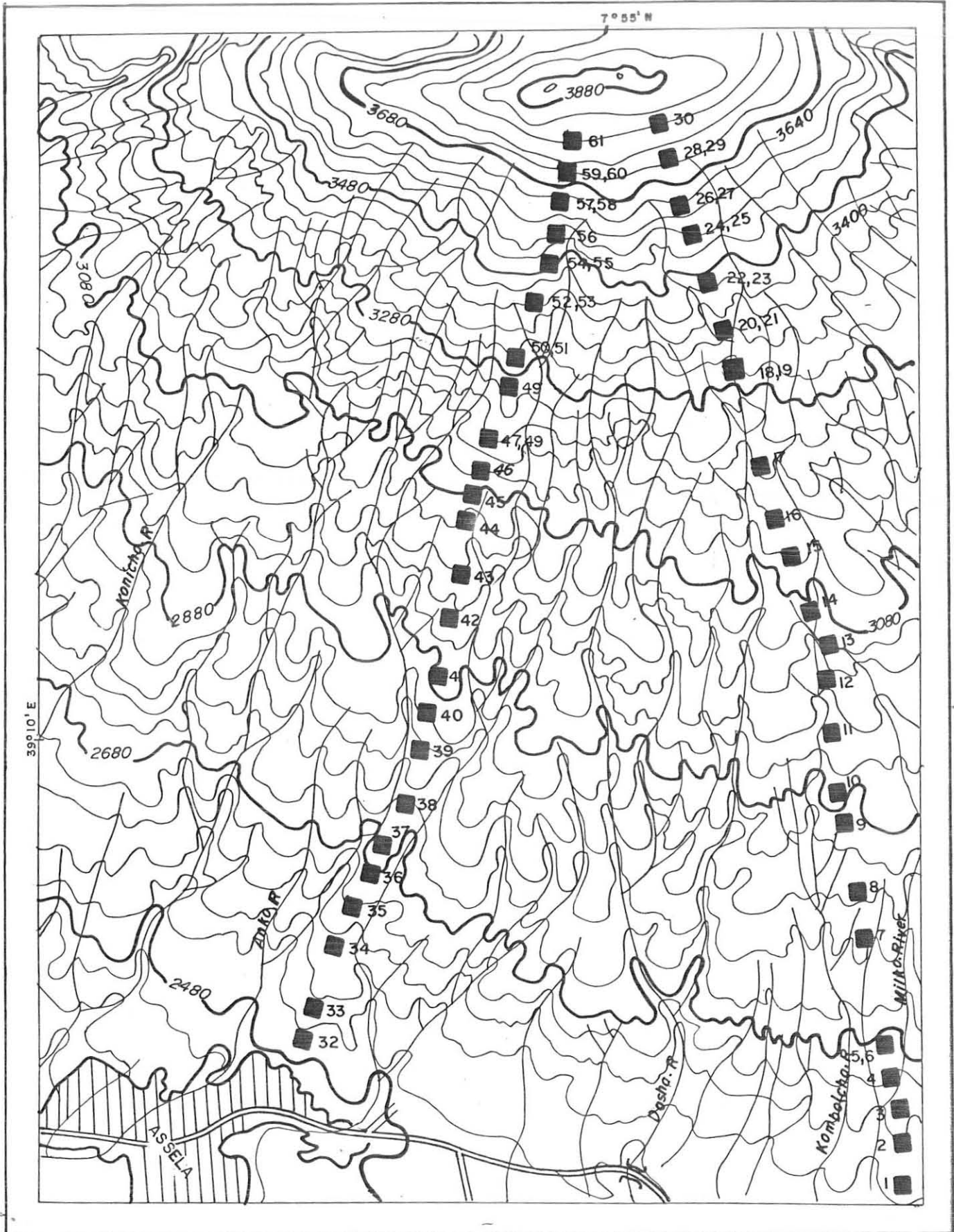
LOCATION OF THE STUDY AREA

Map 1



THE STUDY AREA

Map 2



LEGEND

continuity of this lava flow to higher elevations, under the cover of the plateau pyroclastics and the other younger products of Chilalo itself, (Bekele, 1982 p.24).

2.1.3. Climate

There are no meteorological observations in the study area. So it is difficult to present the microclimatic details. However, it is possible to describe the area as part of the moist cooler plateau of the Chilalo Ranges.

One can also observe that the rise in elevation from the foothill to the top of the study area is accompanied by a corresponding decrease of temperature. Daniel in his analysis of monthly temperature categories reports that areas with altitude above 3000m have daily average temperature between 13° to 16°C during the warmest months and less than 13°C during the coldest months. For altitudes 2300-3000m the warmest months range between 16° to 20°C and the coldest months 13° to 16°C , (Daniel, 1974 p.16).

According to Daniel's classification of rainfall regimes in the country, the Arsi Highlands (the study area included) fall in Regime 1A which is characterized by eight rainy months (from March to October) and no 'small rains', (Daniel, 1974 p.7).

If one considers the temperature-altitude and potential evapotranspiration (PE) relationships, it is possible to see low water losses and high rainfall in highlands resulting from a decrease in PE with increase in altitude. For highlands with altitude above 3000m (commonly known as 'wurch' or alpine), for example, the PE is 80 cms while for altitudes between 2300 - 3000m ('dega' or temperate) it is 80 - 110 cms, (Daniel, 1974 p.16).

2.1.4. Soils

The soils in the study area change from dark to reddish brown (at altitudes 2500 - 3000m) and are generally darker in color at altitudes above 3000m. Under good natural vegetation cover the soils have good structure, though in many parts of the study area this has been affected due to the increasing cultivation practices and so decrease in the vegetation cover. The soils are generally found to be acidic with a pH ranging mostly from 5.0 to 6.0. (Soils will be discussed in greater detail in the chapters under Results and Discussion).

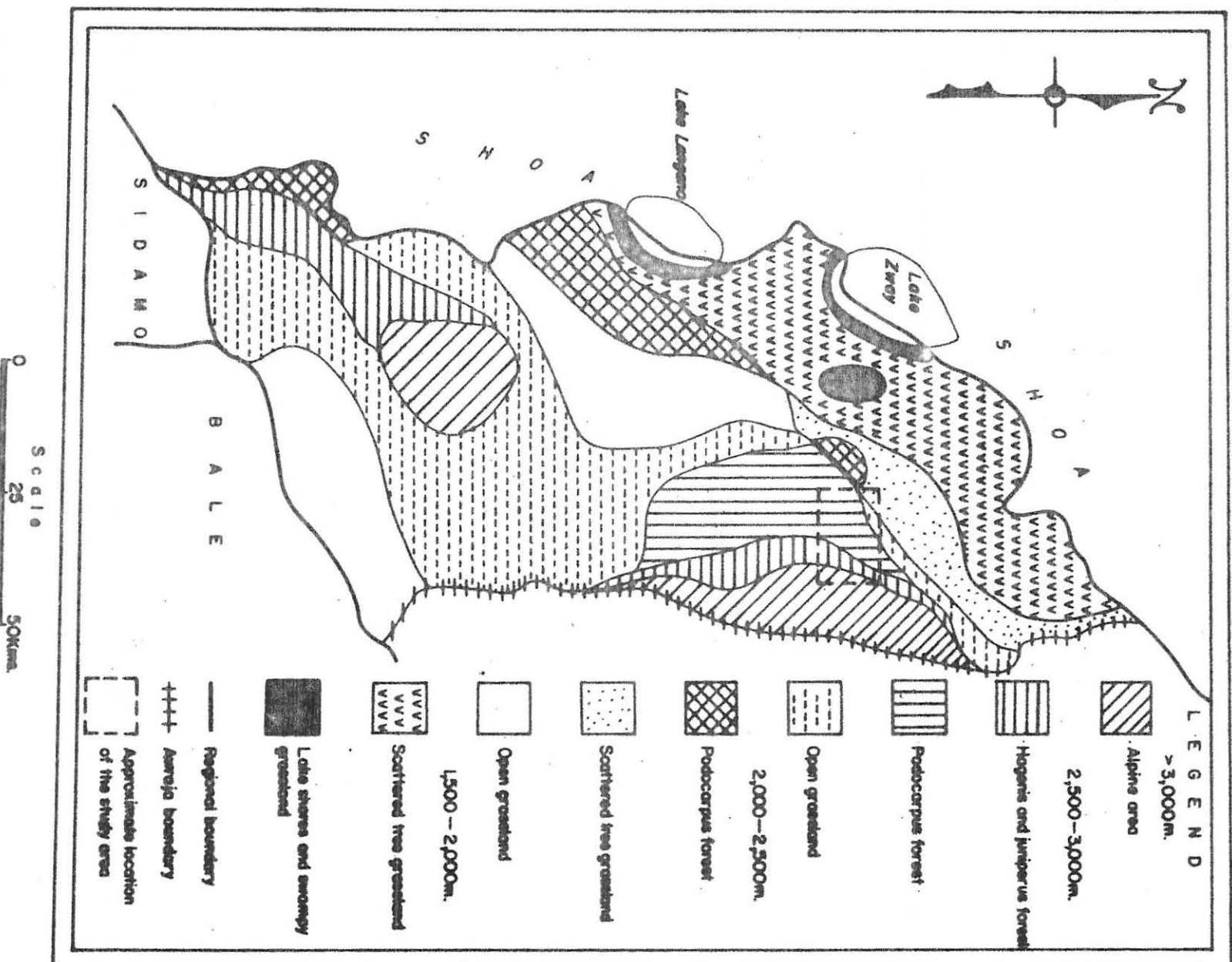
2.1.5. Vegetation and Land Use

Starting from the foothills to the top of the mountain, the study area covers a wide range of vegetation types. Hackansson (1968 as quoted by Alemayehu, 1975 p.37), by considering the relationship between altitude and vegetation, has classified the Chilalo Awraja into four ecological zones, namely Alpine (above 3000m), Highland Area (2500 - 3000m), Medium Altitude (2000 - 2500m) and Lowland Area (1500 - 2000m). This study is based on the first two zones - Alpine and Highland Areas. It is from these parts that the environmental and vegetation data were collected.

The Alpine area, with Erica arborea as the main species, is the upper limit for tree growth and has a very clear ecological borderline. The topography is mountaneous and steep, rarely flat. The herbaceous vegetation in this area consists of perennial herbs and clumped perennial grasses, (Alemayehu, 1975 p.37). This area is characterized by frequent burning of Erica arborea.

ECOLOGICAL CLASSIFICATION OF THE VEGETATION CHICALO AMRAJA (AFTER HACKANSSON)

MAP 3



The Highland Area (2500 - 3000m) is the upper limit for some plants occurring below 2500m. The general topography is gently rolling to steep hills frequently intersected by gorges of the major river systems. It is characterized by forests in which the major tree species are Hagenia abyssinica, Juniperus procera and Podocarpus gracilior and also by open grassland.

Most of the people in the study area are mixed farmers. Some obtain all their earnings from selling wood from the forests to the inhabitants in Assela. Those who live on the borders of Erica arborea and adjacent to the Hagenia and Juniperus forests are inclined more towards animal rearing than crop production. The open grasslands and the undulating areas and river valleys of the Podocarpus forests are mostly favored for cultivation. Barley is the most important crop grown in the area.

2.2. Review of Related Literature

2.2.1. Sampling

Since measurement and expression of everything in an environmental complex is difficult, the use of sampling becomes imperative. However, to establish meaningful environmental relationships to vegetational units, sampling should be done with maximum care, planning and least bias.

In any kind of vegetational sampling, segmentation of the vegetation cover or recognition of entities, selection of samples in the recognized segments, the decision of what size and shape the sample plots should be and the decision of what to record once the plots are established should be taken into consideration, (Mueller-Dombois et.al. 1974 p.31).

In explaining vegetational sampling, Greig-Smith (1964, p.20) reports that with few exceptions the object in making quantitative estimates of vegetation will fall into one or other of the three categories:

- a) an estimate of the overall composition of the vegetation within certain boundaries, with a view to comparison with other areas or with the same area at another time
- b) the investigation of variation within the area or
- c) correlation of vegetation differences with differences in one or more habitat factors.

This division, according to Greig-Smith, is not absolute but it is worth making, because, for instance, the most useful procedure for sampling for overall composition may not be the most satisfactory for examination of variation within the area. Sometimes a comparison is possible whereby more than one objective may be attained, although perhaps at a lower level of precision, by suitable sampling procedures.

Once the site of the study is chosen, one may use the single plot or multiplot sampling method. Besides being subjective in assessing whether or not the area sampled is large enough to reflect the characteristics of that particular community, the single plot method can be useful only in true homogeneous areas, (Kershaw, 1975 p.175). In multiplot method, however, the sample is spread over each vegetation segment (in heterogeneous areas) as much as possible in the form of small stands or plot samples. Moreover, individual quadrat sizes are adjusted primarily to the convenience of assessing the quantitative parameters selected, (Mueller-Dombois et.al. p.47). The multiplot

method is, therefore, preferred by many workers than the single plot method.

To select sample stands in recognized vegetation segments, random or systematic sampling may be used. Each of these has its merits and demerits. So the choice of the sampling procedure depends on the purpose of the study. As Greig-Smith (1964 p.21) puts it, a sampling procedure must always be related to the importance of the information sought, to the problem under investigation and to the degree of precision necessary.

In random sampling, since the placement of samples within an area is entirely through chance, there is a possibility that any point within the area has an equal chance of being represented and bias is eliminated. The advantages of random sampling, which systematic sampling lacks, are the availability of an estimate of the mean value and an estimate of the precision of this mean, (Greig-Smith 1964 p.21).

However, inspite of the advantages of random sampling mentioned above, systematic sampling, characterized by a grid of regularly distributed samples across the vegetation segment, has been preferred by many workers because it is more representative of variations over the area resulting in a better correlation between vegetation and environment than random samples, (Greig-Smith, 1964 p.22). Moreover, it is easier to carry out in the field.

The choice of shape and size of stands in a vegetational study depends on many factors important among which are the type and intensity of the study and also the investigator's choice,

Mostly stands are square in shape but can also be rectangular. The variance between rectangular strips was markedly less than between squares (Clapham, 1952 as quoted by Sebbibe, 1980 p.7). However, in using rectangular stands, as Greig-Smith (1964, p.24) points out, the problem of exaggerated edge effect similar to those found with very small quadrats needs consideration.

Regarding the size of stands, Greig-Smith (1964) reports that the smaller the stand the greater the length of stand boundary per unit area and consequently the greater the chance of significant edge-effects (like problems incurred by shape) due to the observer consistently including individuals that ought to be excluded or vice-versa. He suggests, therefore, that quadrats should not be too small especially if individuals of the species under consideration have a large area or ill-defined boundary at ground level.

2.2.2. Vegetation Classification

2.2.2.1. The Community and Continuum Concepts

A plant community is not a random aggregation of plants but an organized complex with a typical floristic composition and morphological structure which have resulted from the interaction of species populations through time, (Shimwell, 1971 p.1). It is the result of numerous abiotic factors (like soil, temperature, rainfall, humidity, light intensity, winds, altitude, slope etc) and biotic factors - the various interactions among the plants and animals in the respective community.

The two well known theories in the study of plant communities are the Community (vegetational discontinuity) and Continuum (vegetational continuity) concepts.

According to the community concept, vegetation is composed of well defined, discrete units which can be combined to form abstract classes, (McIntosh, 1967). It emphasizes that each species has a distribution which is related to a total range of environmental factors and which depends upon the limits of its own population dynamics, (Shimwell, 1971 p.235). The supporters of this concept exclude the transition zones between adjacent communities because they consider these zones as negligible compared to the vegetation around. The principle thus argues that there are, more or less, sharply defined boundaries between one community and another.

Clements (1916), Tansley (1920), Du Rietz (1921) who expressed that transitions are insignificant relative to the associations themselves; Ludi (1929) who observed that in the Alps areas dwarf shrubs were often sharply bounded but that grassland communities were mixed and interspersed without clear boundaries; Dahl (1957) who observed discontinuity of some and continuity of other communities in Norwegian Mountains, are some of the supporters of the Community Concept, (Whittaker, 1962 pp 88-89).

The Continuum Concept, unlike the Community Concept, argues changes in vegetation cover are continuous, gradual and thus clear cut differentiation of communities is not possible, (McIntosh, 1967 p.137). Accordingly, therefore, discontinuities in natural vegetation are not to be observed (or are rare) except where there discontinuities in the physical environment as at the junction between the outcrops of different geological strata. Such a discontinuity is regarded by Whittaker, (1962 p.89) as a complex mixture of continuity and relative discontinuity.

Among the earliest authors who recognized and advocated for the Continuum Concept is Gleason (1926), whose work was later on adapted and developed by Mutuszkowicz (1948); by Curtis and his associates especially Curtis and McIntosh (1951), Brown and Curtis (1952), Curtis (1959) and by Whittaker (1952, 1956, 1960). Other contributors to this concept are Goodall (1954a) and Greig-Smith (1964).

In connection with these two theories, McIntosh (1967 p.159) points out that both the Continuum and Community Concepts are variously assessed and criticized and contrary to the early tendency of taking them as mutually exclusive, both are viewed more recently as simply a matter of preference or even as complementary with no real conflict.

2.2.2.2. Classification or Ordination?

Classification and Ordination are two important methods of vegetation study used to summarize and simplify the bulk of raw data. In classification, the stands are arranged in groups, on the basis of presence and absence of plant species, the members of which have certain properties in common; in ordination the stands are arranged on axes, with their properties determining their positions, (Cragg, 1964 p.72).

Though there is a common misconception that classification and ordination are mutually exclusive and linked respectively with the community and Continuum concepts, this argument has diminished significance nowadays. In theory, these two approaches, as Greig-Smith (1964 p.158) puts it, may seem quite distinct from each other while practically the divergence is not so great as might appear.

Regarding the similarity of the two approaches, many workers have given their opinions. An initial classification may lead to an

ordination (Curtis and McIntosh, 1951; Curtis, 1955; Cragg, 1964); an ordination may lead to classification arbitrarily into segments (Curtis 1959, King 1962) or a more involved sequence of classification and ordination procedures developed (Ream 1963, Groenwoud 1965a, Orlocci 1967 as quoted by McIntosh, 1967 p.168). Goodall (1963) and Greig-Smith (1964) consider ordination and classification methods and agree that they are not necessarily incompatible (McIntosh, 1967 p.168).

Now that both approaches are considered equally appropriate it seems difficult to establish a hard and fixed rule as to when to classify and when to ordinate. As many researchers suggest, therefore, the choice of method in a vegetational study should rest mainly on the insight of the user and on convenience (both in the performance of the analysis and in the use of the results).

2.2.2.3. Methods of Vegetation Classification

The process of classification is essentially the summarization for each sample of the information in many numbers (dozens to hundreds of species abundance) into a single number (a cluster assignment), (Gauch, 1982 p.175). Its primary function is to construct classes for making inductive generalizations and the particular classes constructed always arise in connection with a particular purpose, (Gilmour, 1951 as quoted by Sebsibe, 1980 p.12).

That the lack of dependable information on the vegetation of an area is a major problem in planning forest exploitation and or conservation is cited by many workers. As possible solutions to this problem, Webb et.al. (1967 as quoted by Sebsibe, 1980 p.13)

suggest the categorization of the forest either by ordination or classification, the establishment of a procedure for allocating new sites to the existing categories and to what extent these categories reflect environmental factors. Moreover, for a proper landuse (as to whether the area should remain a forest or be put to agricultural use), they report that existing knowledge relating known environments and management plans should be systematized.

In the past, to classify the vegetation of an area, different workers were considering different factors (like dominance of major species, floristic association, succession etc.). In light of the time consumed, laboriousness of classification and the difficulty in assessing the consistence of the individual ecologist's work and its agreement with the work of others, early classification techniques were considered to be subjective and informal, (Goodall, 1953; Whittaker, 1962; Sokal, 1974 as quoted by Gauch, 1982 p.173). At present, however, it is not difficult to follow an ecologist's work.

There are different kinds of classificatory method. Pielou (1969) and Gauch (1982) have tried to point out the main differences. Following are three characteristics for distinguishing among the methods:

a) Hierarchical or Reticulate

In hierarchical classification classes are arranged into a hierarchy and so classes at any level are subclasses of classes at a higher level. In reticulate classification, where each entity is assigned to a cluster, the clusters are defined separately and the links between them have the form of a network rather than a tree. Since the hierarchical classification is less cumbersome, easier to

understand and more widely used in ecological work, it is mostly preferred by many researchers, (Pielou, 1969 p.238).

b) Divisive or Agglomerative

In a divisive classification we begin with the whole collection of stands and divide and redivide it to arrive at progressively smaller classes stopping when each class contains a single member or when the predetermined limit of some stopping rule is reached. In an agglomerative classification we start at the bottom and work upward, beginning with the individual stands and combining and recombining them to form successively more inclusive groups, (Pielou, 1969 p.239; Gauch, 1982 p.177).

c) Monothetic or Polythetic

In a monothetic classification sets of samples are divided according to the presence or absence of a single attribute (like the possession of a particular species). In a polythetic classification, two groups are combined or separated on the basis of their overall similarity. Here the entire species composition of samples are considered in the process of deriving cluster assignments (Pielou, 1969 p.240; Gauch, 1982 p.178).

According to Pielou (1969 p.239), computations are simpler in divisive classification since the subdivision process may not continue to the point at which individual stands are recognized as classes. Moreover, divisive classification is mostly free from the bad combinations, which may also affect all subsequent combinations, that may be made at an early stage in the agglomerative process. This is because, unlike the agglomerative process, it does not begin

with the smallest units (the stands themselves) which are most likely to obscure the true affinities.

2.2.2.4. Technique chosen for Classification

Developed by Williams and Lambert (1959, p.99), Association Analysis is a hierarchical, divisive, monothetic method of classification. It is applicable for stands with a list of species they contain.

Many workers have used this technique for the study of different types of communities. Among them are Kershaw (1967) on Tropical Savanas, Austin and Greig-Smith (1968) on Tropical Rainforests, TewoldeBerhan (1975) on a Woodland Grassland in Ethiopia, Sebsibe (1980) on a Montane Forest in Ethiopia, Gittins (1965) on Temperate Grasslands, Zerihun (1980) on Montane Grassland Vegetation in Ethiopia, Harrison (1970, 1971) on Heaths and Hailu (1982) on a Forest in Ethiopia. For the purpose of this study also, Association Analysis was used.

As Pielou (1969 pp.240-241) puts it, the argument in Association Analysis is that if any pair of species in the vegetation exhibits association, either positive or negative, the vegetation is taken to be heterogeneous and so classifiable. The stands are to be classified by dividing them into groups within which no interspecies associations remain. Then each group can be regarded as homogeneous. To do this we first divide the whole collection based on the species that shows the greatest degree of association (which Pielou names as a 'critical species') with other species. The set of stands is divided into a group that contains the species and another that lacks the species. This division of each of the groups (which are taken as new sets) is repeated until the groups are ultimately reached in which there are

no significant associations.

To determine the critical (indicator) species, Williams and Lambert suggest the calculation of an index of association between every possible pair of species by using three possible measures namely chi square, chi square corrected and the square root of chi square divided by the total number of stands.

The occurrence of the two species for which the index is being calculated is entered in the following 2X2 contingency table:

		Species X		
		+	-	
Species Y	+	A	B	A+B
	-	C	D	C+D
		A+C	B+D	N

where A = number of stands in which both species X and Y occur

B = number of stands in which Y but not X occurs

C = number of stands in which X but not Y occurs

D = number of stands in which neither X nor Y occurs

The association is measured by either of the following indices:

$$X^2 = \frac{(AD-BC)^2 N}{(A+B)(C+D)(A+C)(B+D)}$$

$$\text{Corrected } X^2 = \frac{(AD-BC-N/2)^2 N}{(A+B)(C+D)(A+C)(B+D)}$$

$$\frac{X^{\frac{1}{2}}}{N} = \frac{(AD-BC)^2 N^{\frac{1}{2}}}{(A+B)(C+D)(A+C)(B+D)}$$

contribution of all these results in a slow and stunted growth making altitude important in plant distribution, (Toumey et.al. 1947; Hedberg 1964 as quoted by Hailu 1982 p.75).

Slope affects runoff and removal of nutrients from the surface. It also affects drainage since drainage increases with increasing slope. By so doing, slope contributes to the downward leaching of oxygenated water in well drained soils and to acidity in poorly drained soils.

Though according to Etherington (1975 p.246), the very marked differences between the natural vegetation of acid and alkaline soils seem to arise from either nutritional disturbances or from nutritional effects on the soil microflora, and that variations in the soil pH as such does not directly influence growth, pH plays a very important role in indicating the chemical state hence availability of some important nutrients which plants get from the soil.

Low pH values, for example, are often associated with coarse texture, with low cation exchange capacity and easy leaching thus suffering losses of easily mobilized elements such as calcium, magnesium and potassium, (Etherington, 1975 p.245). Low pH values are also signs of reduced microbial activities and thus retardation of mineralization of organic matter, (Buckman et. al., 1969 p.387).

pH, therefore, is a good guide for predicting which plant nutrients are likely to be deficient or not. However, since in some habitats, according to Tewolde (1975 p.54), species can survive by keeping their roots at different levels and the average pH is hardly indicative of the pH that a plant is subjected to, the range of pH is more meaningful.

Conductivity gives information on the total amount of water soluble salts many of which are important plant nutrients in the soil, (Thompson et.al. 1971 p.282). High conductivity is associated with a high supply of soluble salts.

Soil texture affects the resistance to root penetration, extent and degree of branching of the roots, the infiltration of water, the rate of water movement and the water holding capacity. Texture is also associated with fertility. The finer the texture of the soil the greater its fertility since the fraction of a soil may be likened to a vast store house in which mineral nutrients accumulate and from which they may be drawn as the plant needs them, (Daubenmire, 1961 p.19). Sandy soils, for example, weather very slowly (meaning slow release of nutrients) and are, therefore, characterized by low cation exchange capacity. Generally, therefore, marked differences in texture help to explain the plant-soil relationships.

Soil color, which is distinctly influenced by the oxidation status of iron (Buckman et.al. 1969), indirectly indicates the nature of the soil. Buckman et.al. report that the removal of excess quantities of hydrated form of iron should take place when sufficient oxygen is present. As a result yellow, red and reddish brown colors are encouraged by well oxidized conditions while black color indicates less oxidized conditions in which ferrous oxide predominates.

Soil color is also associated with soil depth and slope (and thus with drainage). The shallower the reddest soil color depth the more waterlogged is the soil. Similarly, the lower the value of the soil color hue and the deeper the reddest color from the surface, the better drained is the soil (Tewolde, 1975 p.53).

CHAPTER 3

RESULTS

Based on the information of presence and absence of species, the vegetation in the 60 stands under study was classified into 14 groups (A,B,C,D,E,F,G,H,I,J,K,L,M,N) out of which 5 groups (A,B,C,E,F) consisted only of one stand each and were rejected from being compared with the other groups, see fig. 1.

Groups D,G,H and I are identified by the presence of Erica arborea while groups J,K,L,M and N are without it. All in all, out of the total of 60 stands, 36 stands were classified in the former major group (i.e. +E. arborea) and 24 in the latter (i.e. -E. arborea)

To compare the nine groups (D,G,H,I,J,K,L,M,N) among themselves and see how much the environmental factors have contributed in the formation of these groups, t-tests were computed (see appendices 2 to 36) The probability 0.05 was used as the level of significance in the test.

From table 1 one can see that, generally, there are more significant contrasts at surface level (0-10 cms) than at subsurface (20-90 cms) level. And comparing all the variables at surface level, altitude has the highest number (23) of significant contrasts.

Though statistical significance tests help us to assess the reliability of observed differences and similarities, non significance of quantified data does not necessarily imply the absence of cause and effect relationships since it may arise as much from the inadequacy of the quantification process as from the genuine absence of such relationships, (Toumey et.al. 1947 as quoted by Hailu, 1982 p.74).

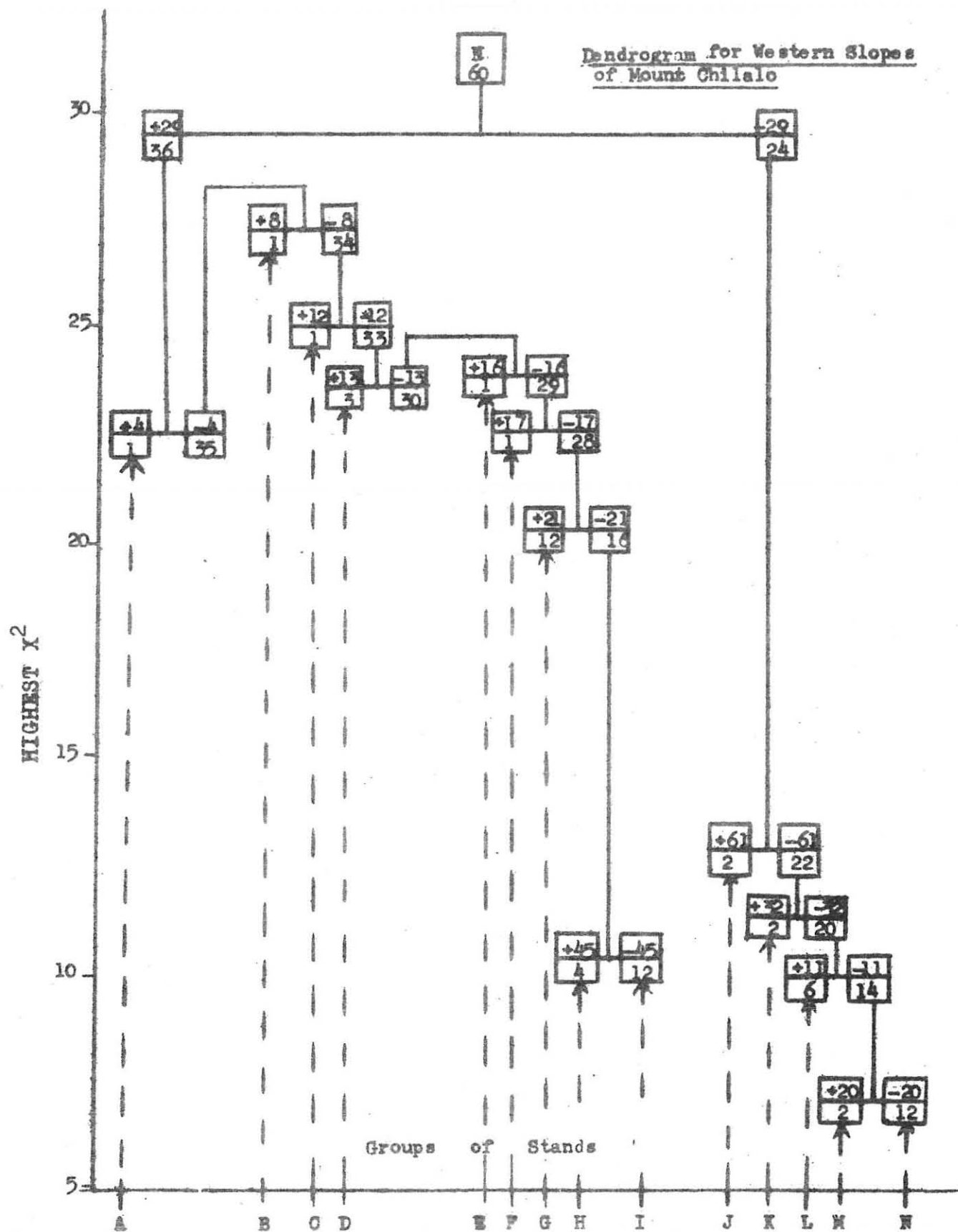


Fig. 1 - ASSOCIATION ANALYSIS GROUPS

Therefore, for those comparisons whose tests were not statistically significant, mean values were used to see possible contrasts between the groups.

Table 1

Total Number of Significant Contrasts for the Nine Groups
(at the probability of 0.05)

<u>Variable</u>	<u>Number of Significant Contrasts</u>		
	<u>Surface</u>	<u>Subsurface</u>	<u>Overall av.</u>
Soil Color Hue	16	19	19
pH	14	6	7
Conductivity	15	12	1
Calcium	11	3	-
Magnesium	14	10	6
Potassium	9	5	3
Sodium	5	6	6
Manganese	17	11	7
Sand	9	6	6
Clay	14	9	6
Silt	7	6	6
Altitude	23	NR	NR
Slope	5	NR	NR

NR - Not Recorded

Table 2
Stand Composition of the Groups

<u>Groups</u>	<u>Stand Number</u>
A	14
B	40
C	47
D	46, 48, 49
E	44
F	55
G	24, 25, 26, 27, 28, 29 30, 52, 53, 56, 57, 58
H	13, 16, 17, 18
I	19, 20, 21, 22, 23, 45 50, 51, 54, 59, 60, 61
J	5, 35
K	1, 12
L	6, 8, 9, 15, 36, 39
M	41, 42
N	2, 3, 4, 7, 10, 11 32, 33, 34, 37, 38, 43

Following is the list of groups of stands and the species by which they were identified:

Group A - consists of one stand. It is identified by the presence of Erica arborea and Maytenus arbutifolia.

Group B - consists of one stand and is identified by the presence of E. arborea, the absence of M. arbutifolia and the presence of Hypericum revolutum.

- Group C - consists of one stand and is identified by the presence of E. arborea, the absence of M. arbutifolia, H. revolutum, and the presence of Myrsine africana.
- Group D - consists of three stands and is identified by the presence of E. arborea, the absence of M. arbutifolia, H. revolutum, M. africana and the presence of Gnidia glauca.
- Group E - consists of one stand and is identified by the presence of E. arborea, the absence of M. arbutifolia, H. revolutum, M. africana, G. glauca and the presence of Discopodium penninervium.
- Group F - consists of one stand and is identified by the presence of E. arborea, the absence of M. arbutifolia, H. revolutum, M. africana, G. glauca, D. penninervium and the presence of Schefflera volkensii.
- Group G - consists of twelve stands and is identified by the presence of E. arborea, the absence of M. arbutifolia, H. revolutum, M. africana, G. glauca, D. penninervium, S. volkensii and the presence of Helichrysum splendidum.
- Group H - consists of four stands and is identified by the presence of E. arborea, the absence of M. arbutifolia, H. revolutum, M. africana, G. glauca, D. penninervium, S. volkensii, H. splendidum and the presence of Spilanthes mauritiana.
- Group I - consists of twelve stands and is identified by the presence of E. arborea and the absence of all the other species mentioned in group H.
- Group J - consists of two stands and is identified by the absence of Erica arborea and the presence of Crepis carbonaria.

Group K - consists of two stands and is identified by the absence of E. arborea, C. carbonaria and the presence of Andropogon chrysostachys.

Group L - consists of six stands and is identified by the absence of E. arborea, C. carbonaria, A. chrysostachys and the presence of Rapanea simensis.

Group M - consists of two stands and is identified by the absence of E. arborea, C. carbonaria, A. chrysostachys, R. simensis and the presence of Olinia aequipetala.

Group N - consists of twelve stands and is identified by the absence of all the species mentioned in group M.

CHAPTER 4

DISCUSSION

The vegetation in the study area was divided into two major groups identified by the presence and absence of Erica arborea. These two groups will be designated as +E. arborea and -E. arborea.

4.1. Comparison between +E. arborea and -E. arborea groups

Table 3 shows the mean values of the environmental factors by which +E. arborea and -E. arborea groups are characterized. As can be seen from the table, except for pH ranges and pH at 0-10 cms depth, the two groups are characterized by distinct differences in most of the variables. The t-tests (table 4) computed to compare the +E. arborea and -E. arborea groups show statistically significant contrasts in soil color hue, electrical conductivity, sand, clay, silt, altitude, slope and magnesium content.

Altitude, which results in climatic differences, is a very important environmental factor determining the distribution of species associated with +E. arborea and -E. arborea. The average altitude for +E. arborea stands is 3364 meters compared to 2776 meters for -E. arborea stands. Mostly +E. arborea and species associated with it are roughly found above 3000 meters while those species which are not associated with E. arborea are mostly found below 3000 meters.

As can be seen from table 3, +E. arborea group of stands have higher soil color hue showing less oxidized soils. The organic matter and frequent burning of the E. arborea have also contributed to the darker color of soils in +E. arborea group of stands. Moreover, +E. arborea group of stands have also lower conductivity than -E. arborea stands indicating lower supply of soluble salts.

Table 3

Mean Values of Environmental Characteristics of

+E. arborea and -E. arborea

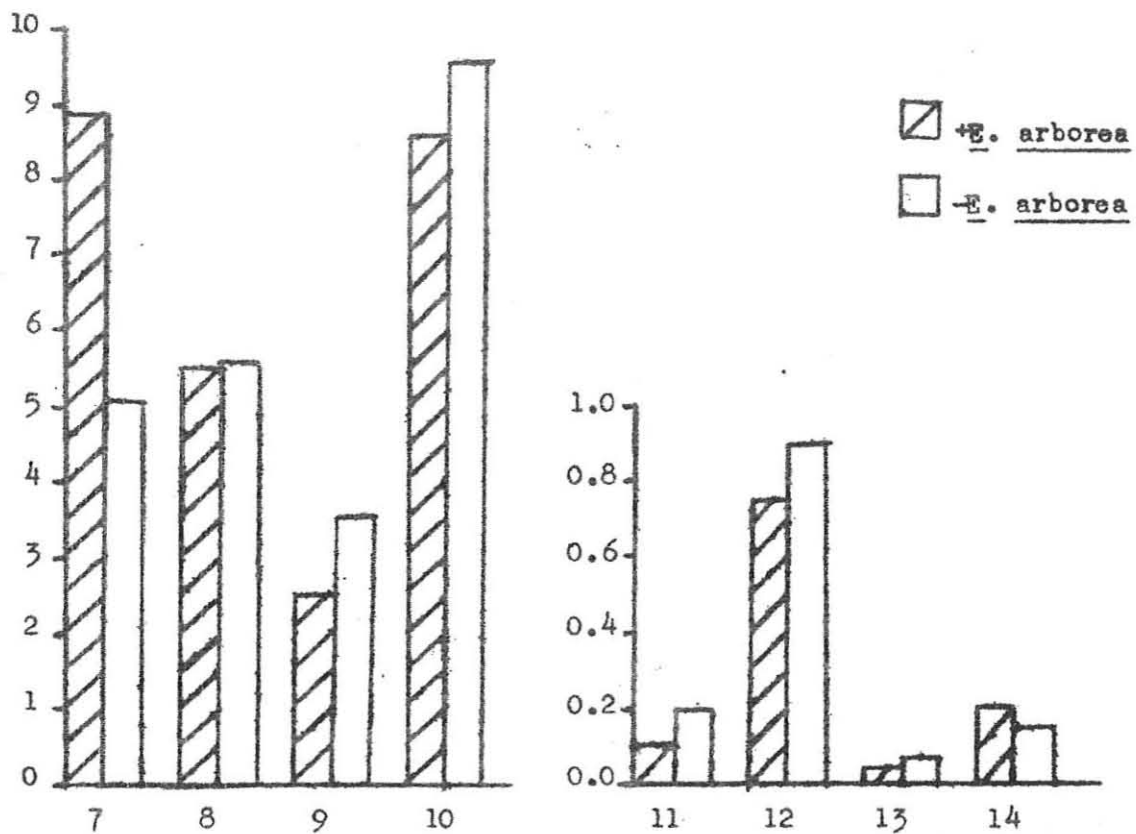
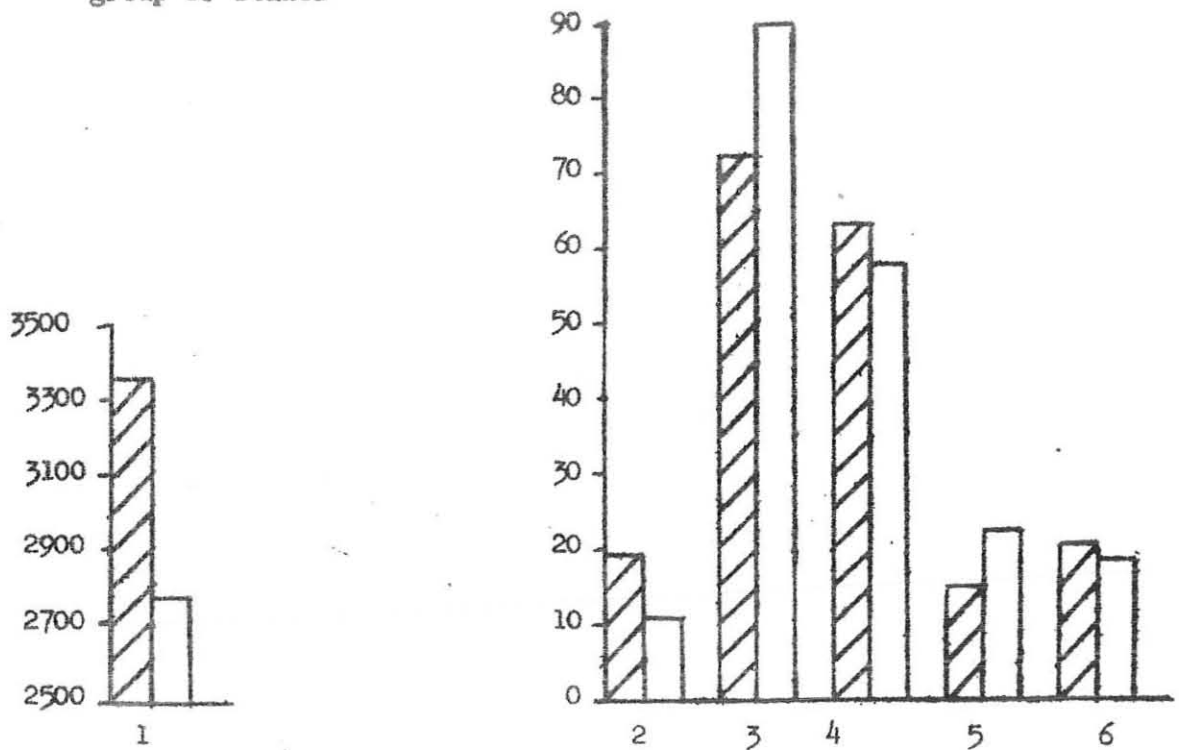
groups of stands

<u>Environmental</u> <u>Factor</u>	<u>+E. arborea</u>	<u>-E. arborea</u>
Soil Color Hue	8.80	5.09
pH (0-10 cms)	5.50	5.60
pH ranges*	5.2 - 5.7	5.6 - 6.1
Conductivity (mmhos/cm)	0.11	0.19
Mg (meq/100gm of soil)	2.28	3.52
K (meq/100gm of soil)	0.75	0.89
Mn (meq/100gm of soil)	0.04	0.06
Na (meq/100gm of soil)	0.21	0.15
Ca (meq/100gm of soil)	8.57	9.59
Soil depth (cms)	72	90
Sand (%)	68.35	58.67
Clay (%)	10.49	22.93
Silt (%)	21.16	18.40
Altitude (meters)	3364	2776
Slope (°)	18.3	11.1

All figures are mean values of the groups.

* Ranges between the low and high mean values of the stands in a group

Fig. 2 - Environmental Characteristics of +E. arborea and -E. arborea group of stands



1. Altitude (m)
2. Slope ° (°)
3. Soil Depth (cm)
4. Sand (%)
5. Clay (%)
6. Silt (%)

7. Soil Colour Hue
8. pH
9. Mg (meq/100gm of soil)
10. Ca (" " " ")

11. Conductivity (mmhos/cm)
12. K (meq/100gm of soil)
13. Mn (" " " ")
14. Na (" " " ")

Table 4

Comparison of

+E. arborea (D,G,H,I) and -E. arborea (J,K,L,M,N)

group of stands using the t-test

Groups Compared	factor	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D,G,H,I to J,K,L,M,N	Color Hue	53	3.61	8.688	0.001
	pH	53	-0.1	0.879	
	E.C.*	53	-0.08	2.454	0.02
	Cations**	53	-0.65	0.607	
	Sand	53	9.68	4.030	0.001
	Clay	53	-12.44	4.868	0.001
	Silt	53	2.76	2.067	0.05
	Altitude	53	888	15.987	0.001
	Slope	53	8.2	3.533	0.001
	Ca	53	-1.74	0.279	
	Mg	53	-1.30	3.983	0.001

*Electrical Conductivity

**
Mg, Ca, Mn, K, Na

Though the statistical tests between the two groups do not show significant contrasts (except for Mg) with respect to the amount of the cations, the mean values show that +E. arborea group of stands have lower Mg, K, Mn, Ca, than -E. arborea groups.. That E. arborea is mostly associated with soils having low nutrient status is also investigated by Sebsibe (1980) in his ecological study on the Menagesha State Forest. The difference in cation content (between the groups) may be attributed to several causes among which can be texture and slope.

Texture affects the cation content. The lower amount of K in +E. arborea groups, for example, can be associated with the lower clay and higher sand content compared to -E. arborea groups. This is because sandy soils have less available K due to their slow weathering character. Moreover they have low cation exchange capacity and, therefore, small amount of exchangeable K.

Low Ca is a characteristic of acid sandy soils while Ca and clay content are often correlated. This may explain the difference in Ca between +E. arborea and -E. arborea group of stands (though the contrast is not significant statistically).

Slope may also contribute to the lower cation content in the +E. arborea groups because they are, relatively, found in a steeper slope (18.3°) than the -E. arborea groups (11.1°). This fact implies higher leaching in the former group.

Generally, therefore, the environment of E. arborea and the species associated with it are characterized by lower conductivity lower cation content, steeper slopes, higher leaching, relatively coarser texture and higher altitude when compared to the environment without E. arborea.

4.1.1. Comparison between +E. arborea, +Gnidia glauca and

+E. arborea, -G. glauca group of stands

The first subdivision among the +E. arborea group of stands was made by Gnidia glauca. Group D was identified by the presence of G. glauca while in groups G, H, and I, G. glauca was absent.

Though not statistically significant, group D was characterized by lower soil color hue (indicating better oxidized soils), wider pH ranges, steeper slopes, deeper and older soils than groups G, H and I (see table 5). Taking these factors into consideration, one would expect high leaching and so a decrease in cation content in group D than in groups G, H, and I. However, soils in group D have higher cation content than groups G, H and I. The statistically significant contrast in cation content between the two groups might be due to the high organic matter in group D. Compared to the stands in the study area, the stands in Group D have the highest number of trees (18 trees per stand). Trees take up more nutrients from the soil than herbs. But they also circulate more of it between themselves and in the soil. A forest environment, therefore, has more nutrients than an environment dominated by herbs. Group D is also characterized by higher conductivity which is associated with a high supply of soluble salts.

Gnidia glauca and species, therefore, associated with it favor relatively well oxidized and well drained soils with higher cation content, and this higher content is maintained by them.

Table 5

Mean Values of Environmental Characteristics of

+E. arborea +G. glauca and -G. glauca

group of stands

<u>Environmental</u> <u>Factor</u>	<u>+E. arborea</u> <u>+G. glauca</u>	<u>+E. arborea</u> <u>-G. glauca</u>
Soil Color Hue	8.33	8.96
pH (0-10 cms)	5.00	5.60
pH ranges	5.0 - 5.6	5.4 - 5.7
Conductivity (mmhos/cm)	0.16	0.09
Mg (me q/100gm of soil)	2.88	2.08
K (me q/100gm of soil)	0.88	0.70
Mn (me q/100gm of soil)	0.06	0.03
Na (me q/100gm of soil)	0.27	0.18
Ca (me q/100gm of soil)	11.50	7.60
Soil depth (cms)	90	66
Sand (%)	64.76	69.54
Clay (%)	12.42	9.85
Silt (%)	22.82	20.61
Altitude (meters)	3205	3418
Slope	20.7	17.5

Fig. 3 - Environmental Characteristics of +E. arborea +G. glauca and +E. arborea -G. glauca group of stands

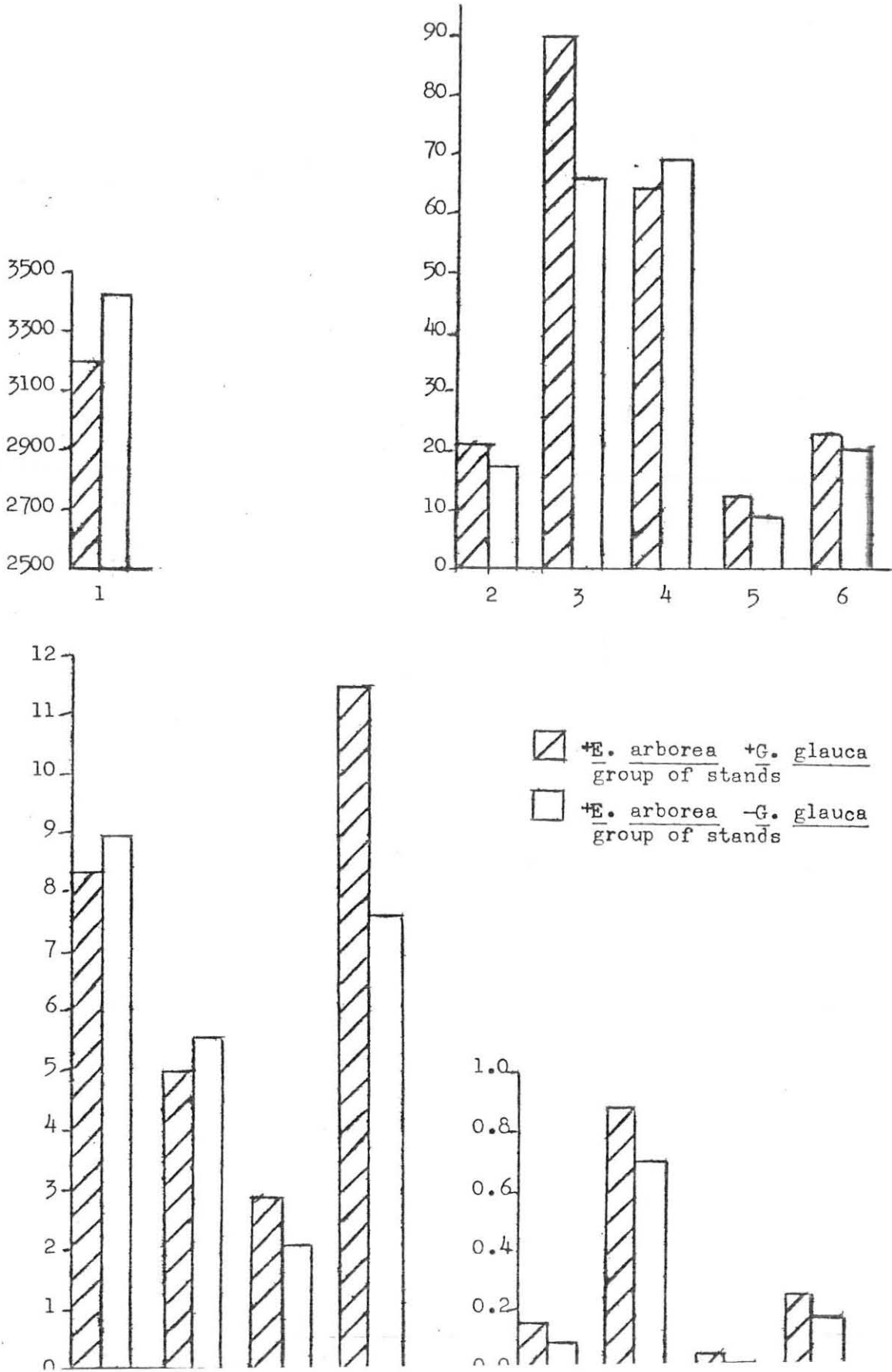


Table 6

Comparison of

+E. arborea +Gnidia glauca (group D)

and -G. glauca (groups G,H, and I) group of stands

using the t-test

<u>Groups Compared</u>	<u>factor</u>	<u>d.f.</u>	<u>$\bar{X}_1 - \bar{X}_2$</u>	<u>t</u>	<u>p</u>
D to G,H,I	Color Hue	29	-0.63	0.884	
	pH	29	-0.60	2.876	0.01
	E.C.	29	0.07	1.080	
	Cations	29	1.01	2.084	0.05
	Sand	29	-4.78	0.851	
	Clay	29	2.57	0.538	
	Silt	29	2.21	0.848	
	Altitude	29	.213	1.666	
	Slope	29	3.20	0.520	

4.1.2. Comparison between +E. arborea -G. glauca +Helichrysum
splendidum (group G) and -H. splendidum (groups H and I)

Further subdivision among groups of +E. arborea stands was made by Helichrysum splendidum. These two groups have statistically significant contrasts in soil color hue and altitude, see table 8.

Relatively group G has less cation content than groups H and I. Even though not statistically significant, the two groups have difference in texture and this fact might have contributed to the difference in cation content.

4.1.3. Comparison between +E. arborea -G. glauca -H. splendidum
+Spilanthes mauritiana (group H) and -S. mauritiana (group I)
group of stands

The last division among the +E. arborea group of stands was made by Spilanthes mauritiana which resulted in group H (+E. arborea -G. glauca -H. splendidum +S. mauritiana) and group I (-S. mauritiana).

As can be seen from table 9, the mean values show clear soil color difference (though not statistically significant) between the two groups with group H having lower soil color hue (better oxidized soils) than soils in group I. Except for altitude, which has statistically significant test with a probability of 0.05, the two groups do not have marked differences in texture, slope, cation content, conductivity and pH.

4.2. Comparison among the -E. arborea group of stands

4.2.1. Comparison between -E. arborea +Crepis carbonaria (group J)
and -C. carbonaria group of stands (groups K,L,M and N)

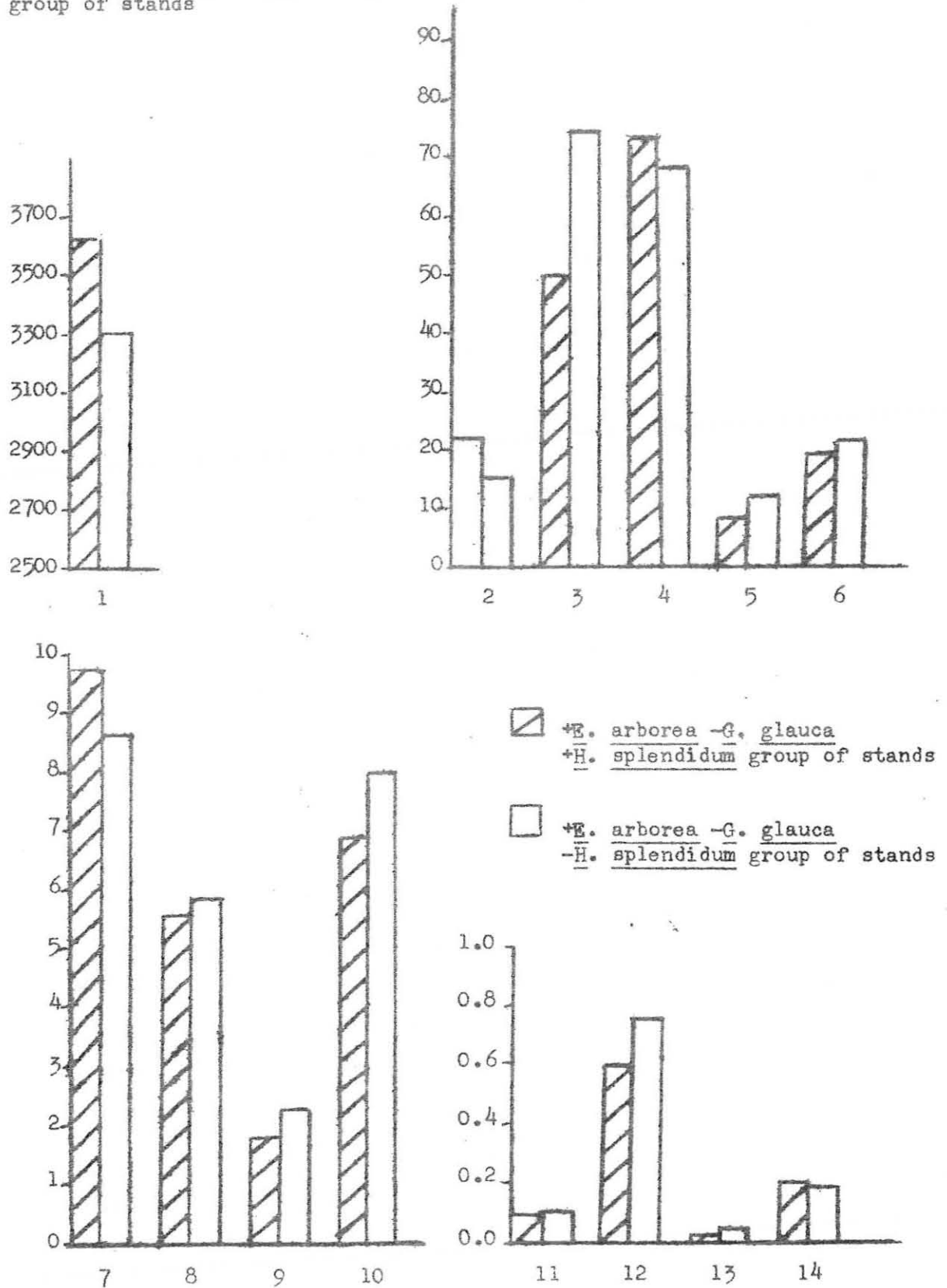
The first division among the -E. arborea group of stands was made by the presence and absence of Crepis carbonaria. Group J is

Table 7

Mean Values of Environmental Characteristics
of +E. arborea -G. glauca +Helichrysum splendidum
and -H. splendidum group of stands

Environmental Factor	+E. arborea -G. glauca +H. splendidum	+E. arborea -G. glauca -H. splendidum
Soil Color Hue	9.72	8.58
pH (0-10cms)	5.6	5.8
pH ranges	5.4 - 5.6	5.6 - 5.8
Conductivity (mmhos/cm)	0.08	0.10
Mg (meq/100gm of soil)	1.76	2.24
K (meq/100gm of soil)	0.59	0.76
Mn (meq/100gm of soil)	0.02	0.04
Na (meq/100gm of soil)	0.19	0.18
Ca (meq/100gm of soil)	6.85	7.97
Soil depth (cms)	50	74
Sand (%)	72.92	67.85
Clay (%)	7.87	10.84
Silt (%)	19.21	21.31
Altitude (meters)	3617.5	3317.5
Slope (°)	21.9	15.3

Fig 4 - Environmental Characteristics of E. arborea - G. glauca
+ Helichrysum splendidum and E. arborea - G. glauca - H. splendidum
group of stands



1. Altitude (m)
2. Slope (°)
3. Soil depth (cm)
4. Sand (%)
5. Clay (%)
6. Silt (%)

7. Soil Colour Hue
8. pH
9. Mg (meq/100gm of soil)
10. Ca (" " " ")

11. Conductivity (mmhos/cm)
12. K (meq/100gm of soil)
13. Mn (" " " ")
14. Na (" " " ")

Table 8

Comparison of

+E. arborea -G. glauca +Helichrysum splendidum (G)

and -H. splendidum group of stands (H,I)

using the t-test

<u>Groups Compared</u>	<u>factor</u>	<u>d.f.</u>	<u>$\bar{X}_1 - \bar{X}_2$</u>	<u>t</u>	<u>p</u>
G to H,I	Color Hue	26	1.14	2.759	0.02
	pH	26	-0.20	1.482	
	E.G.	26	-0.02	0.524	
	Cations	26	-0.40	0.322	
	Sand	26	5.07	1.542	
	Clay	26	-2.97	1.023	
	Silt	26	-2.10	1.405	
	Altitude	26	300	4.184	0.001
	Slope	26	6.60	1.846	

Table 9

Mean Values of Environmental Characteristics of
+E. arborea -G. glauca -H. splendidum +Spilanthus mauritiana
and -S. mauritiana groups of stands

Environmental Factor	<u>+E. arborea</u> <u>-G. glauca</u> <u>-H. splendidum</u> <u>+S. mauritiana</u>	<u>+E. arborea</u> <u>-G. glauca</u> <u>-H. splendidum</u> <u>+S. mauritiana</u>
Soil Color Hue	7.63	9.52
pH (0-10 cms)	5.9	5.6
pH ranges	5.8 - 6.0	5.4 - 5.6
Conductivity (mmhos/cm)	0.08	0.11
Mg (meq/100gm of soil)	2.26	2.22
K (meq/100gm of soil)	0.68	0.68
Mn (meq/100gm of soil)	0.04	0.03
Na (meq/100gm of soil)	0.15	0.21
Ca (meq/100gm of soil)	7.88	8.06
Soil depth (cms)	90	58
Sand (%)	66.70	69.00
Clay (%)	12.69	8.99
Silt (%)	20.61	22.01
Altitude (meters)	3175	3460
Slope (°)	14	16.7

Fig. 5 - Environmental Characteristics of +E. arborea -G. glauca -H. splendidum
+Spilanthus muarilana and -S. maurilana group of stands

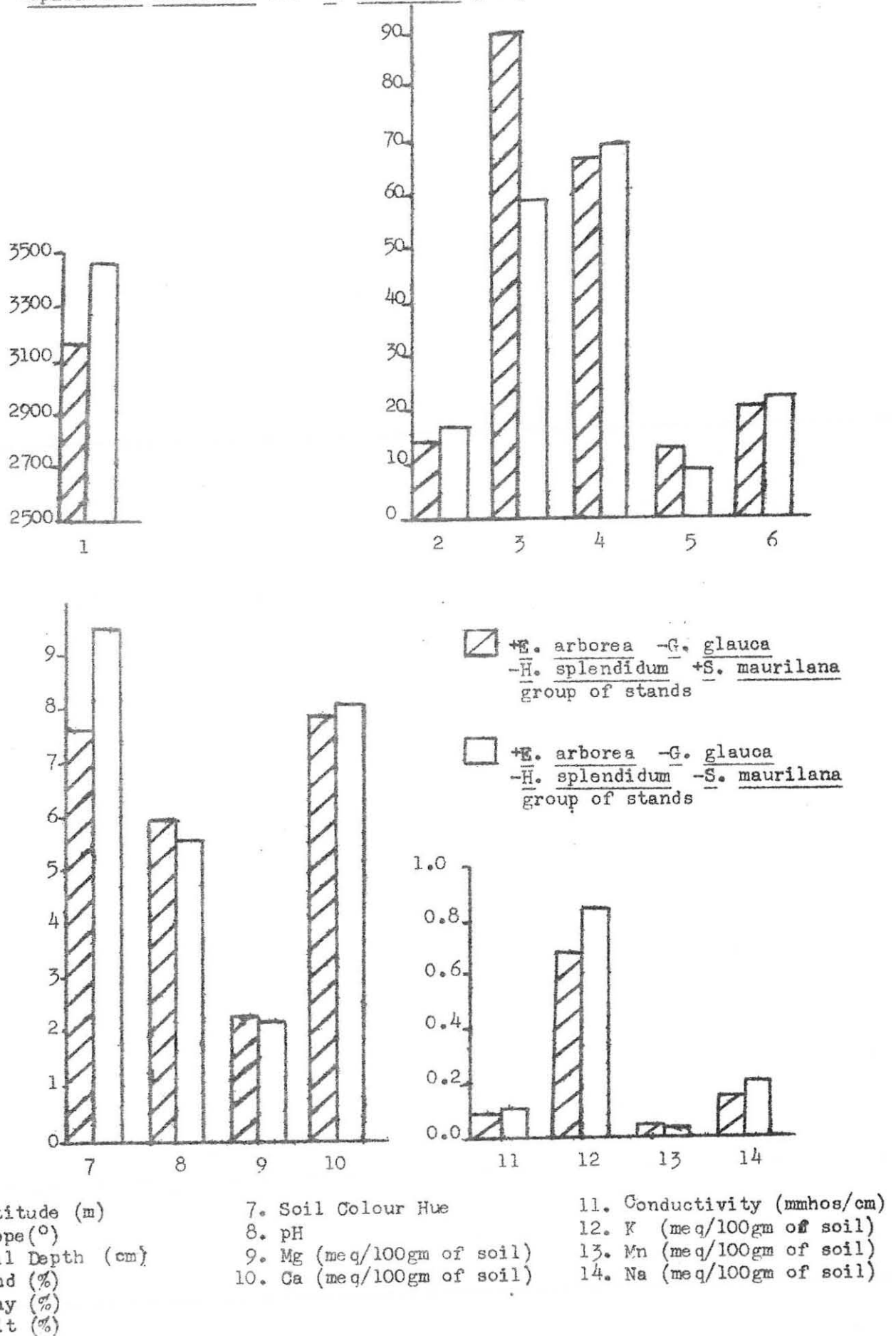


Table 10

Comparison of

+E. arborea -G. glauca -H. splendidum +Spilanthus mauritiana (H)

and -S. mauritiana (I) group of stands

using the t-test

Groups Compared	factor	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
H to I	Color Hue	14	-1.89	0.353	
	pH	14	0.30	1.396	
	E.C.	14	-0.03	0.486	
	Cations	14	-0.07	0.036	
	Sand	14	-2.30	0.395	
	Clay	14	3.70	0.794	
	Silt	14	-1.40	0.523	
	Altitude	14	285	2.572	0.05
	Slope	14	-2.60	0.445	

identified by -E. arborea +C. carbonaria while groups K,L,M and N were without C. carbonaria. These two groups are characterized by statistically significant contrasts in their silt percentage and magnesium content, see table 12.

If one considers the mean values, as can be seen from table 11, group J has lower soil color hue (and so better oxidized soils), higher pH, higher conductivity, and narrower pH ranges (which would mean less leaching) than groups K,L,M and N. Though the two groups do not show statistically significant difference in their clay contents, the higher clay content in group J might have contributed to the higher nutrient status of this group (compared to that of groups K,L,M and N).

4.2.2. Comparison between -E. arborea -C. carbonaria +Andropogon chrysostachys (group K) and -A. chrysostachys (groups L,M,N) group of stands

Further division among the -E. arborea -C. carbonaria group of stands is made by Andropogon chrysostachys forming two groups: group K identified by -E. arborea -C. carbonaria +A. chrysostachys while groups L,M and N did not have A. chrysostachys.

Table 14 shows that the two groups identified by the presence and absence of A. chrysostachys do not have statistically significant contrasts in all the variables considered. Marked differences are, however, seen in the mean values of potassium and calcium where in both cases group K has lower contents. This lower cation content in group K may, most probably, be explained by the lower clay content in this group than in groups L,M, and (see table 13).

Table 11

Mean Values of Environmental Characteristics of

-E. arborea +Crepis carbonaria and -C. carbonaria

groups of stands

<u>Environmental</u> <u>Factor</u>	<u>-E. arborea</u> <u>+C. carbonaria</u>	<u>-E. arborea</u> <u>-C. carbonaria</u>
Soil Color Hue	4.0	5.4
pH (0-10 cms)	5.9	5.5
pH ranges	5.8 - 6.2	5.4 - 6.0
Conductivity (mmhos/cm)	0.24	0.18
Mg (meq/100gm of soil)	4.80	3.21
K (meq/100gm of soil)	1.40	0.76
Mn (meq/100gm of soil)	0.04	0.07
Na (meq/100gm of soil)	0.14	0.16
Ca (meq/100gm of soil)	12.1	9.0
Soil depth (cms)	90	90
Sand (%)	57.10	59.06
Clay (%)	30.30	21.09
Silt (%)	12.60	19.85
Altitude (meters)	2658	2806
Slope (°)	11.0	11.2

Fig 6 - Environmental Characteristics of -E. arborea +Crepis carbonaria and -E. arborea -C. carbonaria group of stands

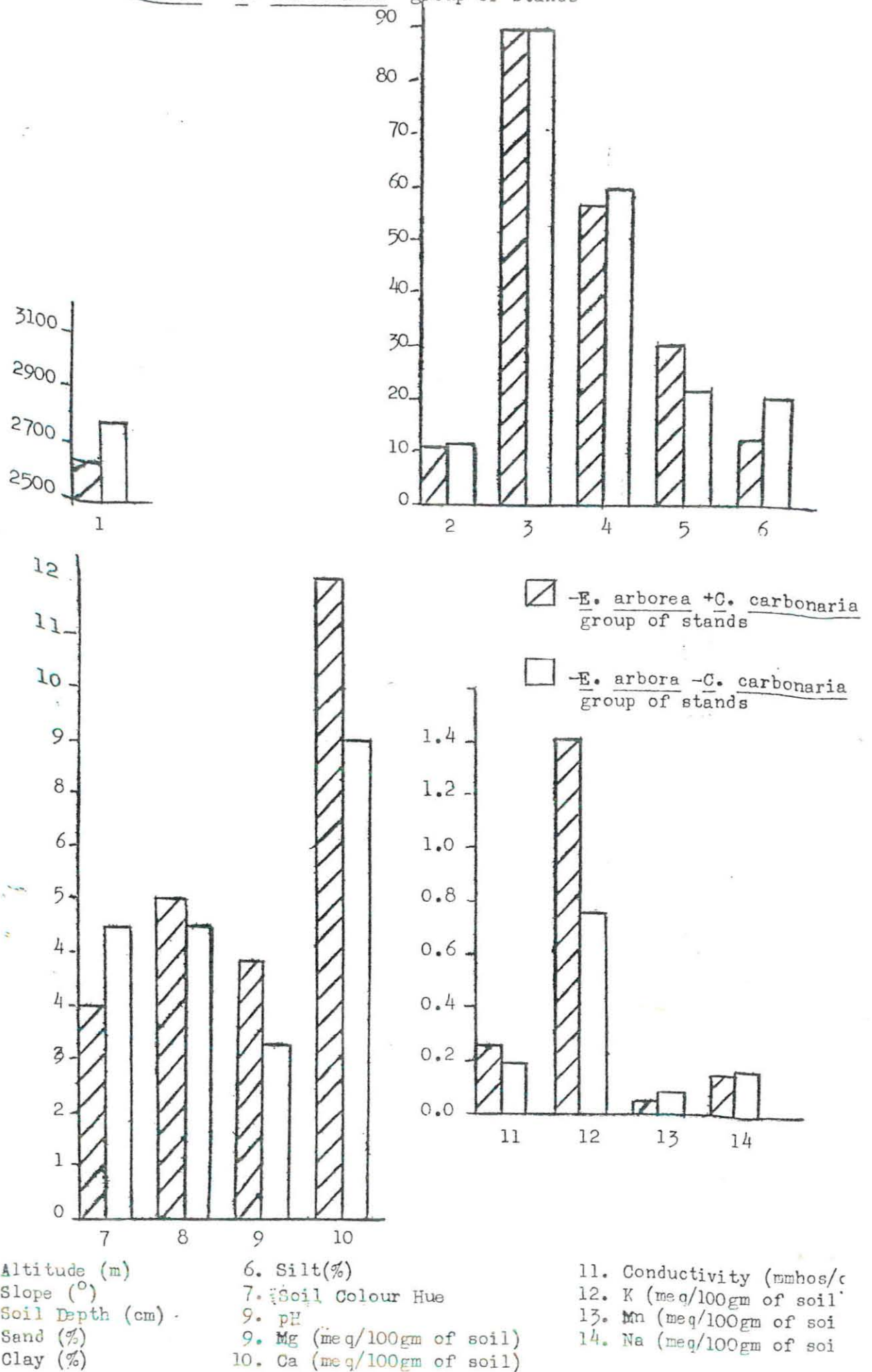


Table 12

Comparison of

-E. arborea +Crepis carbonaria (J) and
-C. carbonaria (K,L,M,N) group of stands
using the t-test

Groups Compared	factor	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
J to K,L,M,N	Color Hue	22	-1.40	1.292	
	pH	22	-0.40	1.562	
	E.C.	22	0.06	0.769	
	Cations	22	0.86	0.363	
	Sand	22	-1.96	0.446	
	Clay	22	9.21	1.574	
	Silt	22	-7.25	2.508	0.02
	Altitude	22	148	1.535	
	Slope	22	-0.20	0.059	
	Mg	22	1.60	2.235	0.05

Table 13

Mean Values of Environmental Characteristics of
+E. arborea -C. carbonaria +Andropogon Chrysostachys
and -A. chrysostachys group of stands

<u>Environmental</u> <u>Factor</u>	<u>-E. arborea</u> <u>-C. carbonaria</u> <u>+A. chrysostachys</u>	<u>-E. arborea</u> <u>-C. carbonaria</u> <u>-A. chrysostachys</u>
Soil Color Hue	5.3	5.4
pH (0-10 cms)	5.5	5.6
pH ranges	5.2 - 5.8	5.4 - 5.9
Conductivity (mmhos/cm)	0.19	0.17
Mg (meq/100gm of soil)	3.21	3.20
K (meq/100gm of soil)	0.55	0.84
Mn (meq/100gm of soil)	0.06	0.07
Na (meq/100gm of soil)	0.14	0.16
Ca (meq/100gm of soil)	7.85	9.34
Soil depth (cms)	90	90
Sand (%)	58.04	59.40
Clay (%)	17.17	22.40
Silt (%)	24.79	18.20
Altitude (meters)	2747.5	2825
Slope (°)	8.0	12.2

Fig. 7 - Environmental Characteristics of -E. arborea -C. carbonaria
+Andropogon chrysostachys
and -A. chrysostachys

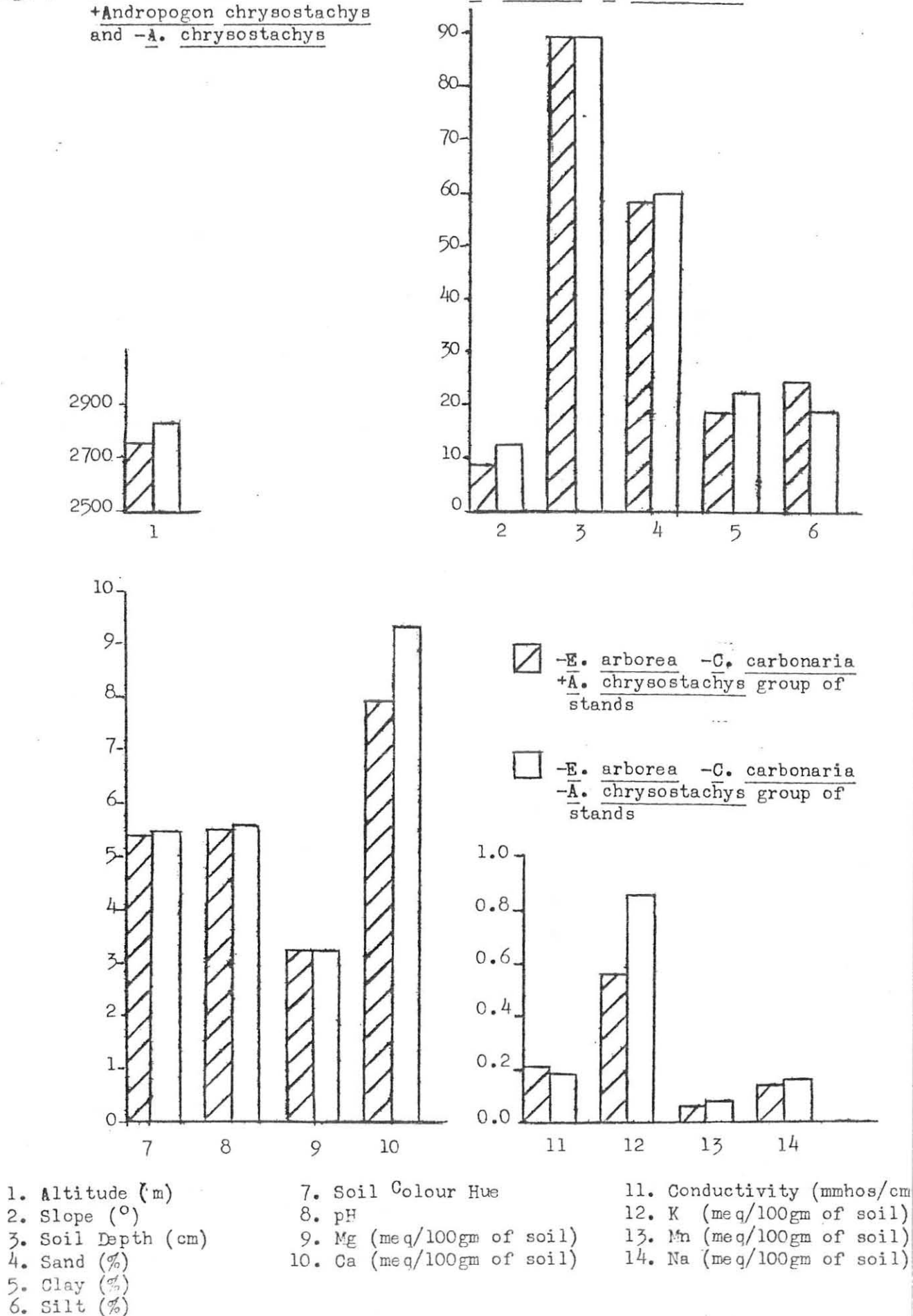


Table 14

Comparison of

-E. arborea -C. carbonaria +Andropogon chrysostachys (K)

and -A. chrysostachys (L,M,N) group of stands

using the t-test

<u>Groups Compared</u>	<u>factor</u>	<u>d.f.</u>	<u>$\bar{X}_1 - \bar{X}_2$</u>	<u>t</u>	<u>p</u>
K to L,M,N	Color Hue	20	-0.10	0.067	
	pH	20	-0.10	0.282	
	E.C.	20	0.02	0.191	
	Cations	20	-0.51	0.158	
	Sand	20	-1.36	0.206	
	Clay	20	-5.23	0.667	
	Silt	20	6.59	1.814	
	Altitude	20	77.5	0.565	
	Slope	20	-4.20	0.868	

4.2.3. Comparison between -E. arborea -C. carbonaria -A. chrysostachys
+Rapanea simensis (group L) and -R. simensis (groups M,N)
group of stands

The next division among the -E. arborea, -C. carbonaria,
-A. chrysostachys is made by the presence and absence of Rapanea simensis.
Group L was identified by the presence of R. simensis while groups
M and N did not have it. The two groups are characterized by significant
contrasts in pH (0-10cms) and electrical conductivity, see table 16.

From table 15 it is possible to see that the mean values of the
two groups, though not supported by statistical tests, show higher
soil color hue (and thus less oxidized soils) and relatively higher cation
content for group L compared to groups M and N. There were no significant
contrasts in texture, altitude, slope and soil depth.

4.2.4. Comparison between -E. arborea -C. carbonaria -A. chrysostachys
-R. simensis +Olinia aequipetala (group M) and -O. aequipetala
(group N) group of stands

The last division among the -E. arborea -C. carbonaria
-A. chrysostachys -R. simensis group of stands was made by the presence
and absence of Olinia aequipetala forming two groups: group M identified
by the presence of O. aequipetala and group N without O. aequipetala.

As can be seen from table 17 there are no statistically significant
contrasts between the two groups. However, though not significant by a
statistical test, group M has low cation content (especially Ca, Mg
and K) and lower conductivity (thus less supply of soluble salts) than
group N.

Table 15

Mean Values of Environmental Characteristics of

-E. arborea -C. carbonaria -A. chrysostachys +Rapanea simensis
and -R. simensis group of stands

Environmental Factor	<u>-E. arborea</u> <u>-C. carbonaria</u> <u>-A. chrysostachys</u> <u>+R. simensis</u>	<u>-E. arborea</u> <u>-C. carbonaria</u> <u>-A. chrysostachys</u> <u>-R. simensis</u>
Soil Color Hue	6.0	5.1
pH (0-10 cms)	6.0	5.4
pH ranges	5.7 - 6.2	5.2 - 5.7
Conductivity (mmhos/cm)	0.22	0.15
Mg (meq/100gm of soil)	3.18	3.22
K (meq/100gm of soil)	0.91	0.81
Mn (meq/100gm of soil)	0.06	0.08
Na (meq/100gm of soil)	0.16	0.17
Ca (meq/100gm of soil)	10.2	8.9
Soil depth (cms)	90	90
Sand (%)	59.9	59.15
Clay (%)	23.3	21.95
Silt (%)	16.8	18.90
Altitude (meters)	2837.5	2818.8
Slope (°)	13.3	11.7

Fig. 8 - Environmental Characteristics of -E. arborea -C. carbonaria
-A. chrysostachys +Raprea simensis and -R. simensis group of stands

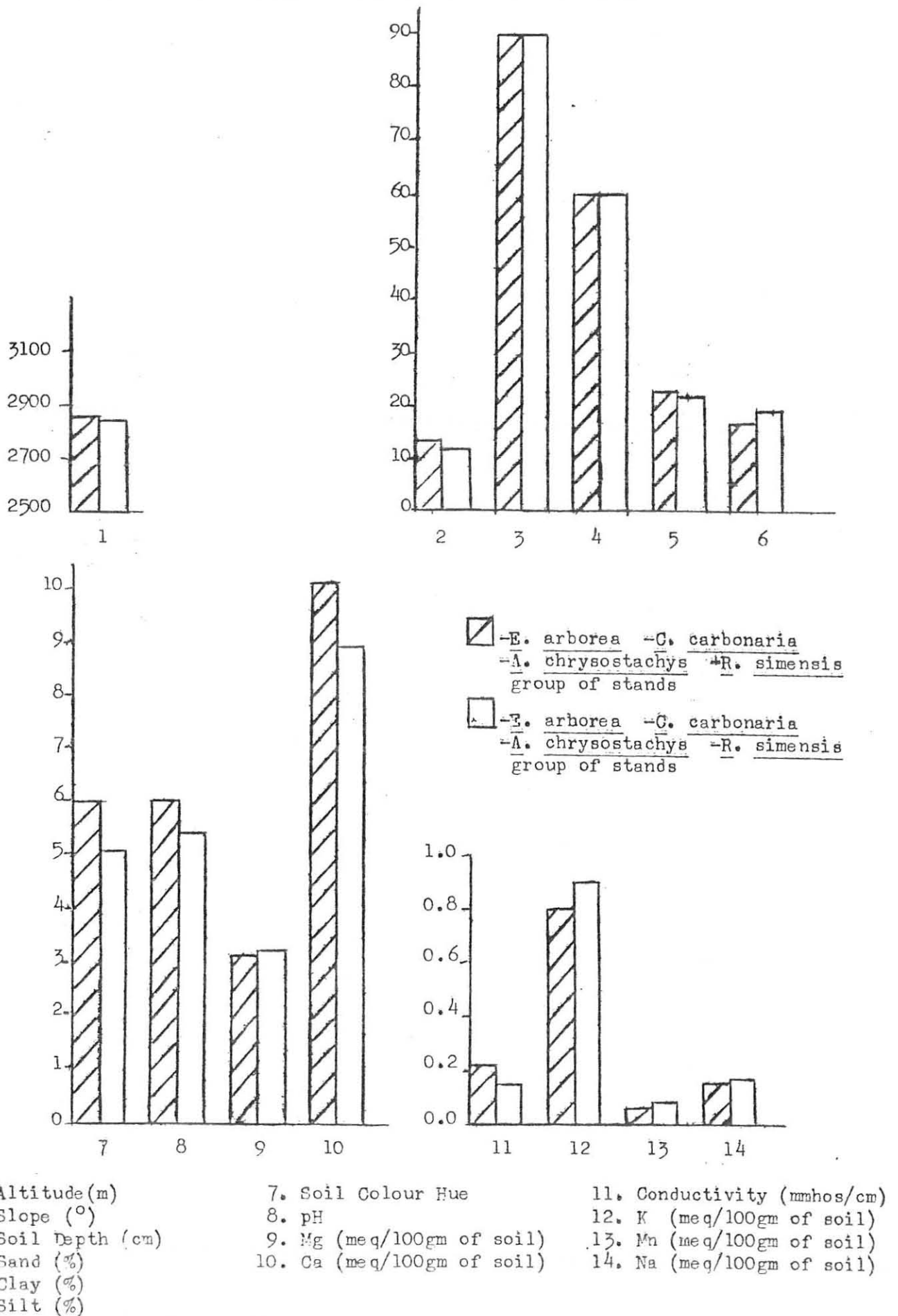


Table 16

Comparison of

-E. arborea -C. carbonaria -A. chrysostachys

+Rapanea simensis (L) and -R. simensis (M,N) group of stands

using the t-test

Groups Compared	factor	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
L to M,N	Color Hue	18	0.90	0.904	
	pH	18	0.60	2.714	0.02
	E.C.	18	0.70	12.681	0.001
	Cations	18	0.05	0.025	
	Sand	18	0.75	0.187	
	Clay	18	1.35	0.259	
	Silt	18	-2.10	0.882	
	Altitude	18	18.7	0.225	
	Slope	18	1.60	0.503	

Table 17

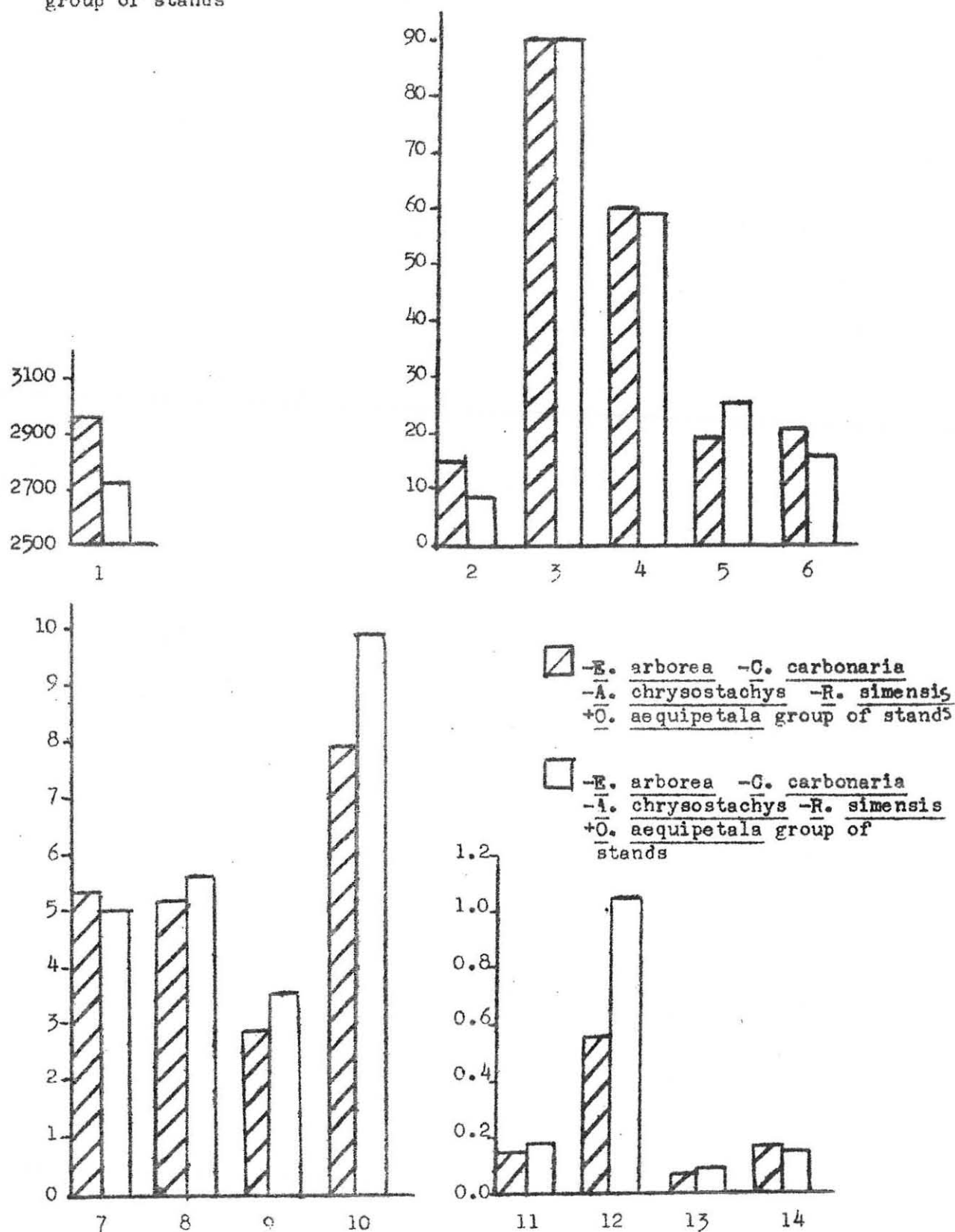
Mean Values of Environmental Characteristics of

-E. arborea -C. carbonaria -A. chrysostachys -R. simensis

+Olinia aequipetala and -O. aequipetala group of stands

<u>Environmental</u> <u>Factors</u>	<u>-E. arborea</u>	<u>-E. arborea</u>
	<u>-C. carbonaria</u>	<u>-C. carbonaria</u>
	<u>-A. chrysostachys</u>	<u>-A. chrysostachys</u>
	<u>-R. simensis</u>	<u>-R. simensis</u>
	<u>+O. aequipetala</u>	<u>-O. aequipetala</u>
Soil Color Hue	5.3	5.0
pH (0-10 cms)	5.2	5.7
pH ranges	5.0 - 5.5	5.4 - 5.9
Conductivity (mmhos/cm)	0.13	0.17
Mg (meq/100gm of soil)	2.87	3.56
K (meq/100gm of soil)	0.56	1.05
Mn (meq/100gm of soil)	0.07	0.08
Na (meq/100gm of soil)	0.17	0.16
Ca (meq/100gm of soil)	7.90	9.92
Soil depth (cms)	90	90
Sand (%)	59.80	58.50
Clay (%)	19.00	24.90
Silt (%)	21.20	16.60
Altitude (meters)	2927.5	2710
Slope (°)	15	8.3

Fig. 9 - Environmental Characteristics of -E. arborea -C. carbonaria
-A. chrysostachys -R. simensis +Olinia aequipetala and -O. aequipetala
group of stands



1. Altitude (m)

2. Slope (°)

3. Soil Depth (cm)

4. Sand (%)

5. Clay (%)

6. Silt (%)

7. Soil Colour Hue

8. pH

9. Mg (meq/100gm of soil)

10. Ca (meq/100gm of soil)

11. Conductivity (mmhos/cm)

12. K (meq/100gm of soil)

13. Mn (meq/100gm of soil)

14. Na (meq/100gm of soil)

Table 18

Comparison of

-E. arborea -C. carbonaria -A. chrysestachys -R. sinensis
+Olinia aequipetala (M) and -O. aequipetala (N) group of stands
using the t-test

Groups Compared	factor	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
M to N	Color Hue	12	0.29	0.208	
	pH	12	0.53	1.646	
	E.C.	12	-0.04	0.315	
	Cation	12	-0.64	0.252	
	Sand	12	1.30	0.214	
	Clay	12	-5.90	0.707	
	Silt	12	4.60	1.178	
	Altitude	12	217.5	1.749	
	Slope	12	6.67	1.271	

The steeper slope and lower clay content in group M might have contributed to the low cation content in this group (compared to group N).

Conditions in group N are the opposite of those in group M. Unlike in group M, relatively higher pH, higher conductivity, gentler slopes and thus less leaching, higher clay content and higher nutrient status are the important characteristics of group N, see table 17.

CHAPTER 5

SUMMARY AND RECOMMENDATIONS

The vegetation in the study are can be broadly classified into four main categories:

Category 1 - identified by +Erica arborea and +Gnidia glauca
group of stands

Category 2 - identified by +Erica arborea and -Gnidia glauca
group of stands

Category 3 - identified by -Erica arborea and +Crepis carbonaria
group of stands

Category 4 - identified by -Erica arborea and -Crepis carbonaria
group of stands

Category 1 - The soils of category 1 are less oxidized than those in categories 3 and 4 but more oxidized than soils in category 2. Soils in category 1 are also characterized by the lowest pH than all the categories. pH ranges of soils in this category are the same as those of category 4 but wider than pH ranges in categories 2 and 3. Category 1 has also the steepest slope among all the categories. The clay content of soils in category 1 is lower than soils in categories 3 and 4 but higher than those in categories 2. The statistical tests of significance for category 1 compared to categories 2, 3, and 4 are shown on table 20a.

The above mentioned facts about category 1 soils would imply that they are exposed to leaching and so are low in nutrient status. However, since the stands in category 1 are located in one of the forest remnants (locally known as Gefersa Forest) of the study area

which might have contributed to high organic matter, the nutrient status is not as low as that of soils in categories 2 and 4 (though lower than those in category 3). Relatively, category 1 is least affected either by burning or cutting for fuel or cultivation. It is located in the transition zone between +Erica arborea and -Erica arborea group of stands.

Category 2 - The soils in this category are the least oxidized among all the categories. As can be seen from table 19, soils in category 2 have higher soil pH (at 0-10cms depth) than categories 1 and 4, but lower than soils in category 3; and the narrowest pH ranges among all the categories. The soil depth in this category, which is the shallowest, indicates that the soils are less leached. The statistically significant contrasts of category 2 compared to categories 1, 3 and 4 are shown on tables 20a and 20b.

Category 2 has gentle slopes than category 1 but steeper slopes than categories 3 and 4 (might indicate high leaching). Moreover the fact that soils in category 2 have the highest sand and least clay content among all the categories contributes to the least cation content than all the categories. This is also the area which has experienced fire hazards several times. All these might have contributed to the low nutrient status of the category.

Category 3 - This category, which is located at the lower altitudes of the -E. arborea stands, is characterized by the most oxidized soils (because of their lowest soil color hue), see table 19. It has also the highest pH, higher conductivity and cation content than all the categories. Tables 20a and 20b show the statistically significant contrasts of category 3 when compared with categories 1, 2 and 4.

Table 19
Mean Values of Environmental Characteristics of
the Four Categories of Vegetation

<u>Environmental</u> <u>Factor</u>	<u>Category</u> <u>one</u>	<u>Category</u> <u>two</u>	<u>Category</u> <u>three</u>	<u>Category</u> <u>four</u>
Soil Color Hue	8.30	9.00	4.00	5.40
pH (0-10 cms)	5.00	5.60	5.90	5.50
pH ranges	5.0-5.6	5.4-5.7	5.8-6.2	5.6-6.0
Soil Depth	90	66	90	90
Conductivity (mmhos/cm)	0.16	0.09	0.24	0.18
Mg (meq/100gm of soil)	2.88	2.08	4.80	3.21
K (meq/100gm of soil)	0.88	0.70	1.40	0.76
Mn (meq/100gm of soil)	0.06	0.03	0.04	0.07
Na (meq/100gm of soil)	0.27	0.18	0.14	0.16
Ca (meq/100gm of soil)	11.50	7.60	12.10	9.00
Sand (%)	64.76	69.54	57.10	59.06
Clay (%)	12.42	9.85	30.30	21.09
Silt (%)	22.82	20.61	12.60	19.85
Altitude (meters)	3205	3418	2658	2806
Slope (°)	20.70	17.50	11.00	11.20

All figures are mean values of the groups of stands in each category.

Fig. 10 - Environmental characteristics of the Four Categories in the study area

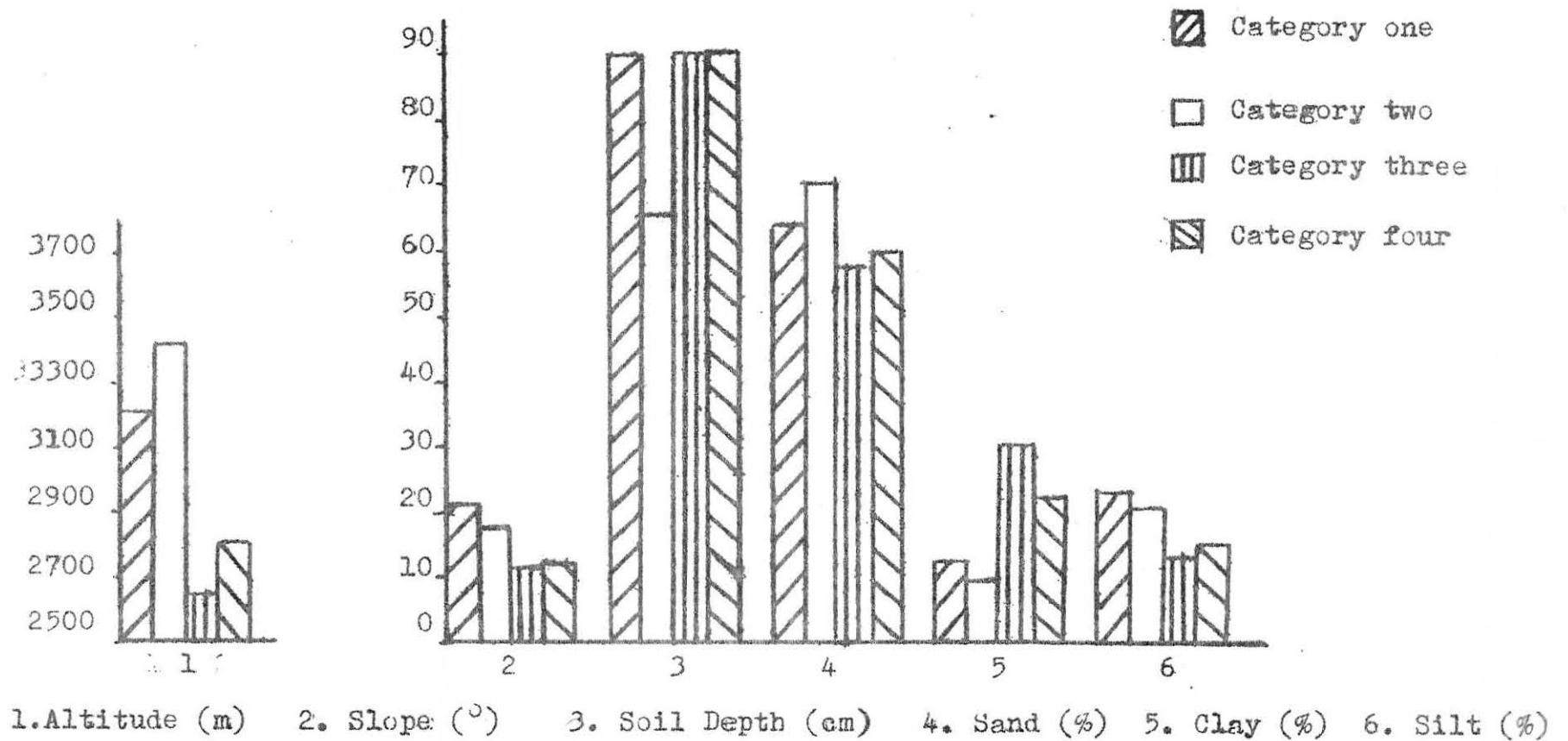


Fig. 11 - Environmental Characteristics of the Four Categories in the study area

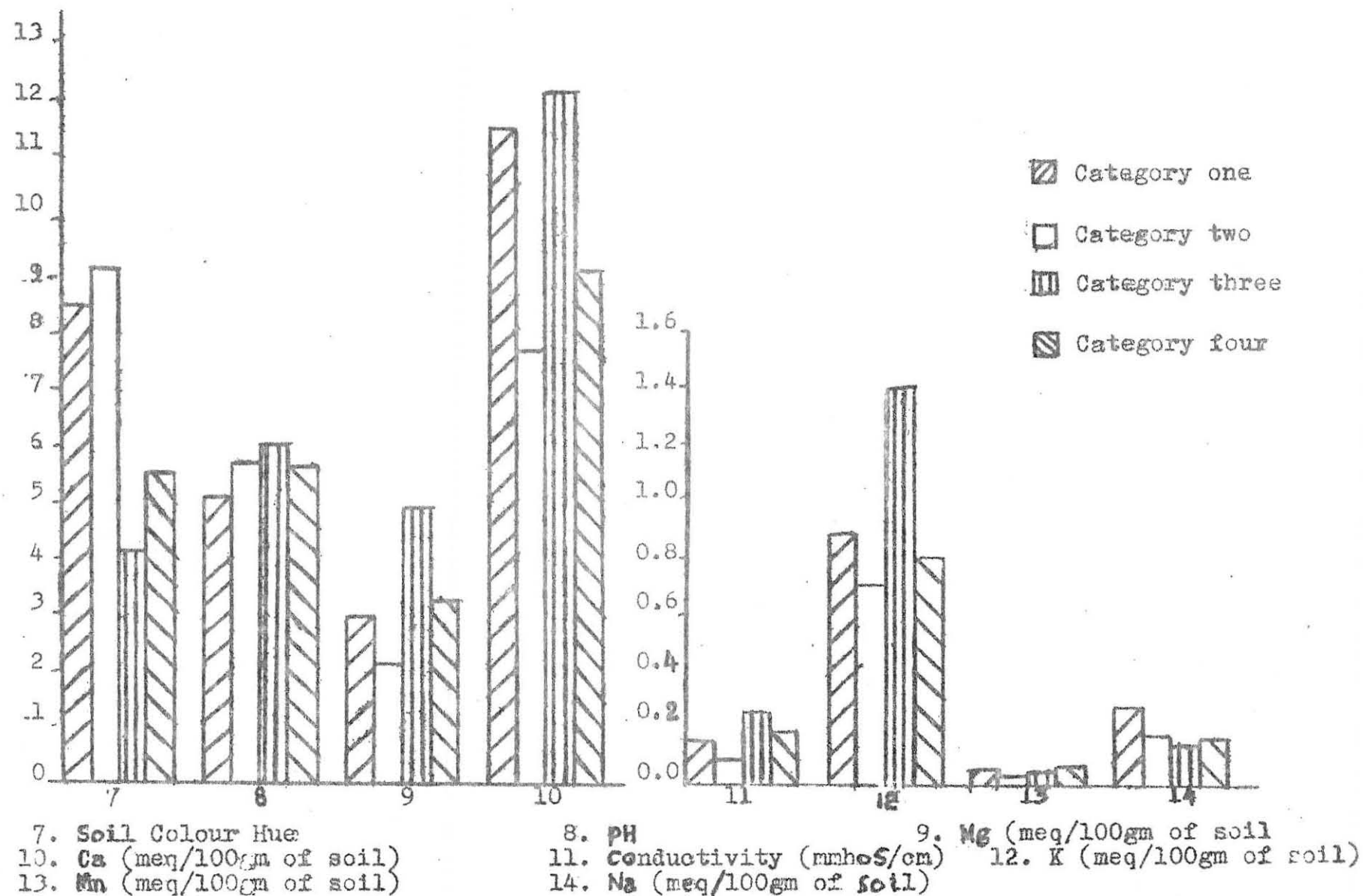


Table 20a
Comparison of the Four Categories of Vegetation
using the t-test

Categories Compared	factor	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
1 to 2	Color Hue	29	-0.63	0.884	
	pH	29	-0.60	2.876	0.01
	E.C.*	29	0.07	1.086	
	Cations**	29	1.01	2.084	0.05
	Sand	29	-4.78	0.851	
	Clay	29	2.57	0.536	
	Silt	29	2.21	0.848	
	Altitude	29	213	1.666	
	Slope	29	3.2	0.520	
	Ca	29	3.9	0.449	
1 to 3	Color Hue	3	4.33	3.663	0.05
	pH	3	-0.90	4.184	0.05
	E.C.	3	-0.08	0.554	
	Cations	3	-0.57	0.137	
	Sand	3	7.66	1.025	
	Clay	3	-17.88	2.069	
	Silt	3	10.22	2.346	
	Altitude	3	547	11.119	0.02
	Slope	3	9.7	1.335	
	Ca	3	-0.60	0.109	
1 to 4	Color Hue	23	2.93	2.453	0.05
	pH	23	-0.50	1.743	
	E.C.	23	-0.02	0.225	
	Cations	23	0.29	0.108	
	Sand	23	5.70	1.143	
	Clay	23	-8.67	1.330	
	Silt	23	2.97	0.887	
	Altitude	23	399	3.700	0.002
	Slope	23	9.5	2.070	0.05
	Ca	23	8.3	6.374	0.001

* E.C. - Electrical Conductivity

** Cations - Mg, Na, Mn, K, Ca

Table 20b
Comparison of the Four Categories of Vegetation
using the t-test

Categories Compared	factor	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
2 to 3	Color Hue	28	4.96	7.738	0.001
	pH	28	-0.30	1.639	
	E.C.*	28	-0.15	2.703	0.02
	Cations**	28	-1.58	0.880	
	Sand	28	12.44	2.509	0.02
	Clay	28	-20.45	4.815	0.001
	Silt	28	8.01	3.641	0.002
	Altitude	28	760	6.643	0.001
	Slope	28	6.50	1.278	
	Ca	28	-4.50	2.377	0.05
2 to 4	Color Hue	48	3.56	7.876	0.001
	pH	48	0.10	0.855	
	E.C.	48	-0.09	2.631	0.01
	Cations	48	-0.72	0.670	
	Sand	48	10.48	4.207	0.001
	Clay	48	-11.24	4.310	0.001
	Silt	48	0.76	0.564	
	Altitude	48	612	10.621	0.001
	Slope	48	6.30	2.634	0.01
	Ca	48	4.40	5.433	0.001
3 to 4	Color Hue	22	-1.40	1.292	
	pH	22	-0.40	1.562	
	E.C.	22	0.06	0.769	
	Cations	22	0.86	0.363	
	Sand	22	-1.96	0.446	
	Clay	22	9.21	1.574	
	Silt	22	7.25	2.508	0.02
	Altitude	22	-1.48	1.535	
	Slope	22	-0.20	0.059	
	Ca	22	3.07	1.117	

* E.C. - Electrical Conductivity

** Cations - mg, Na, Mn, K, Ca

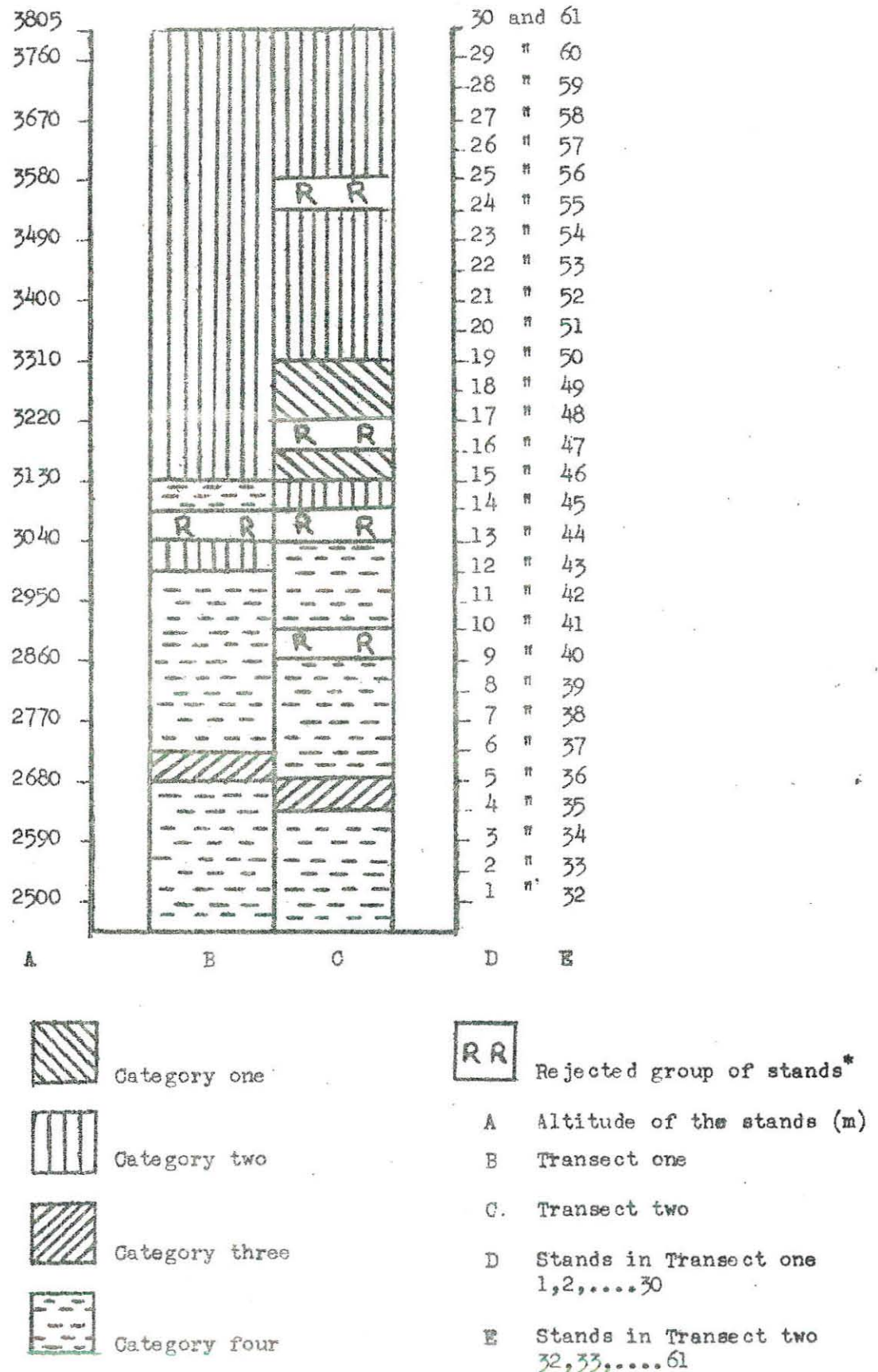
The gentle slope (which helped in decreasing leaching) and the high clay content which is distinct among the other categories (though not statistically significant) must have contributed to the highest nutrient status of soils in category 3 than in any of the categories.

Category 4 - This category has lower soil color hue and so better oxidized soils than categories 1 and 2; but higher soil color hue and so less oxidized soils than in category 3. It has the same pH ranges as category 1 but wider ranges (and so higher leaching) than categories 2 and 3. Soils in category 4 are also characterized by high conductivity and Mg than soils in categories 1 and 2 (but lower than soils in category 3). The statistically significant contrasts of category 4 compared to categories 1, 2 and 3 are shown on tables 20a and 20b.

Generally, in spite of the fact that category 4 is characterized by a gentler slope and higher clay content than category 1 soils, the nutrient status of category 4 is lower than that of category 1. This is most probably the consequence of deforestation for agricultural land and for fuel because this is the category where most of the once dominant Podocarpus and Juniperus forests have been substituted by cultivated land and established settlement. There may be other factors as well which might have contributed to the low nutrient status in this category.

From the results of the several variables (as summarized in table 19) and from observation during fieldwork, there seem to be acute problems especially in categories 2 and 4 which are identified by +E. arborea, -G. glauca and -E. arborea, -G. carbonaria respectively.

Fig. 12 - Diagrammatic Representation of the Four Categories in the Study Area



*These groups were not compared with the other groups because they consisted only of one stand each.

Category 2 has experienced fire hazards several times. The people burn the Erica arborea because they believe that the fresh growth is good for their cattle.

Unlike in category 2, the problem in category 4 is not the burning of forests but the cutting of trees for additional areas of agriculture and for fuel, without any kind of reafforestation programme. Deforestation is increasing in this category so much so that people have started cultivating valley slopes where one would see the forest remnants.

Currently the problems are mostly in the two categories. However the problems may also extend to categories 1 and 3 which at present are in a better position than categories 2 and 4. Therefore, reversal of heavy exploitation of trees and minimizing of grazing areas (which may decrease the burning of E. arborea) ought to be the immediate focus of conservation and management plans in the study area.

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Appendix 1

List of Plant Species Collected From the Sample Stands

<u>Collection N.</u>	<u>Scientific Name</u>
1.	Kalanchoe cfr densiflora Rolfe (H)
2.	Carduus lepro canrus R.E. Fries (H)
3.	Bersama abyssinica Fresen. (T)
4.	Maytenus arbutifolia (Hochst. ex Rich.) Wilcrek. (S)
5.	Asparagus cfr astrati us L. (S)
6.	Maesa lanceolata Forsk. (S)
7.	Vernonia sp. (S)
8.	Hypericum revolutum (T)
9.	Nuxia congesta R. Br. (T)
10.	Pittosporum abyssinicum Hochst. ex Del. (T)
11.	Rapanea simensis (Hochst. ex A. Dc.) Mez. (T)
12.	Myrsine africana L. (S)
13.	Gnidia glauca (Fresen.) Gilg. (T)
14.	Agauria salicifolia (Comm. ex Lam.) Hook. Fil. ex Oliv} (S)
15.	Inula confertiflora A. Rich. (S)
16.	Discopodium penninervium Hochst. (T)
17.	Schefflera volkensii (Harms ex Engl.) Harms. (T)
18.	Crotalaria cfr rosenii (Pax) Milne-Redh. ex Polhill. (S)
19.	Rubus volkensii Engl. (S)
20.	Olinia aequipetala (Del.) Cuf. (T)
21.	Helichrysum splendidum (Thunb.) Less. (S)
22.	Eucalyptus globulus Labill (T)
23.	Solanum campylacanthum Hochst. ex A. Rich. (H)

(T) - Tree

(S) - Shrub

(H) - Herb

Appendix 1

(Cont'd)

<u>Collection N.</u>	<u>Scientific Name</u>
24.	<i>Podocarpus gracilior</i> Pilger (T)
25.	<i>Dovyalis abyssinica</i> (Rich.) Warb. (T)
27.	<i>Rupus apetalus</i> (S)
28.	<i>Hagenia abyssinica</i> (Bruce) Gmelin. (T)
29.	<i>Erica arborea</i> L. (S)
30.	<i>Cyperus fisheranus</i> A. Rich. (H)
31.	<i>Digitaria velutina</i> (Forsk.) P. Beauv. (G)
32.	<i>Andropogon chrysostachys</i> Steud. (G)
33.	<i>Commelina</i> sp. (H)
35.	<i>Bidens pilosa</i> L. (H)
36.	<i>Hypoestes triflora</i> (Forsk.) Roem et. Schult. (H)
37.	<i>Jussiaea</i> sp. (H)
38.	<i>Solanum indicum</i> L. (H)
39.	<i>Cynoglossum amplifolium</i> Hochst. ex DC. (S)
40.	<i>Dichrocephala</i> sp. (H)
41.	<i>Salvia nilotica</i> Juss. ex Jacq. (S)
42.	<i>Satureja paradoxa</i> (Vatke) Engl. (H)
45.	<i>Spilanthes mauritiana</i> (Rich. ex Pers.) DC. (H)
46.	<i>Trifolium semipilosum</i> Fresen. (H)
47.	<i>Crotalaria melanantha</i> (Hochst.) Benth. and Hook. (H)
48.	<i>Stephania abyssinica</i> (Dil. and Rich.) Walp. (H)

(G) - Grass

Appendix I

(Cont'd)

<u>Collection N.</u>	<u>Scientific Name</u>
50.	<i>Galium simense</i> Fresen. (H)
51.	<i>Satureja biflora</i> (Ham. ex Don.) Briq. (H)
53.	<i>Osyris compressa</i> (Berg.) Dc. (T)
54.	<i>Rosa abyssinica</i> R. Br. (S)
55.	<i>Ekebergia capensis</i> (T)
56.	<i>Cyperus rigifolius</i> Steud. (H)
57.	<i>Acroiechaete volkensii</i> Pilger. (G)
59.	<i>Arisaema enneaphyllum</i> Rich. (H)
60.	<i>Asplenium aethiopicum</i> (Burm.) Bech. (S)
61.	<i>Crepis carbonaria</i> Sch. Bip. (H)
62.	<i>Digitaria abyssinica</i> (Hochst. ex Rich) Stapf. (G)
63.	<i>Gnapalium luteo-album</i> L. (H)
64.	<i>Polygonum nepalense</i> Meissn. (H)
65.	<i>Buddleja polystachya</i> Fresen. (S)
66.	<i>Haplocarpha shimperi</i> (Sch. Bip) Beauv. (H)
67.	<i>Rumex bequaertii</i> De Wild. (S)
68.	<i>Viola abyssinica</i> Steud. ex Oliv. (H)
69.	<i>Abutilon logicuspe</i> Hochst. ex A. Rich. (S)
70.	<i>Potentilla reptans</i> L. (S)
71.	<i>Brachypodium flexum</i> Nees. (G)
72.	<i>Juniperus procera</i> Hochst ex Endl. (T)
73.	<i>Galiniera coffeoides</i> Del. (T)

Appendix 1

(Cont'd)

<u>Collection N.</u>	<u>Scientific Name</u>
74.	<i>Plectranthus edulis</i> (Vatke) Agnew (H)
75.	<i>Phytolacca dodecandra</i> L'Her. (S)
76.	<i>Anagallis arvensis</i> L. (H)
77.	<i>Solanum nigrum</i> L. (H)
78.	<i>Achyranthus aspera</i> L. (H)
79.	<i>Plantago palmata</i> Hook. Fil. (H)
80.	<i>Stachys aculeolata</i> Hook. (H)
82.	<i>Thymus serrulatus</i> Hochst. ex Benth. (H)
84.	<i>Alepidea penduncularis</i> Steud. ex A. Rich. (H)
87.	<i>Myrica salicifolia</i> Hochst ex A. Rich. (T)
88.	<i>Conium maculatum</i> (H)
89.	<i>Kniphofia isoetifolia</i> Hochst (S)
90.	<i>Phragmanthera sarertaenis</i> (Hutch. and Bruce) Ined. (T)
92.	<i>Alchemilla abyssinica</i> Fresen. (H)
93.	<i>Ajuga remota</i> Benth. (S)
94.	<i>Helichrysum cymosum</i> L. Less. (S)
95.	<i>Salvia merjamie</i> Forsk. (H)
96.	<i>Carex</i> sp. (H)
97.	<i>Carduus</i> sp. (H)
98.	<i>Euphorbia depauperata</i> Hochst. ex A. Rich. (T)
101.	<i>Bartisia petitiana</i> (A. Rich.) Hemsl. (S)
102.	<i>Helichrysum formosissimum</i> Sch. Bip. ex Rich.
103.	<i>Alchemilla humanii</i> Rotm. (H)
104.	<i>Haplocarpha rueppelli</i> (Sch. Bip.) Beauv. (H)

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appendix 1

(Cont'd)

<u>Collection N.</u>	<u>Scientific Name</u>
105.	Crassula alba Forsk. (H)
106.	Trifolium burchellianum Ser. (H)
107.	Habenaria petitiiana (A. Rich.) Th. Dur. and Schinz. (H)
108.	Albuca sp. (G)
109.	Acabiosa columbaria L. (H)

Appendix 2

Comparison of the groups of stands by pH(surface)

using the t-test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	-0.43	2.818	0.02
H	5	-0.93	4.586	0.01
I	13	-0.44	1.786	
J	3	-0.90	3.971	0.05
K	3	-0.20	-0.881	
L	7	-0.90	7.109	0.001
M	3	-0.35	1.449	
N	13	-0.5	1.443	
G to H	14	-0.5	3.742	0.01
I	22	-0.01	0.076	
J	12	-0.47	2.794	0.02
K	12	0.23	1.367	
L	16	-0.47	4.767	0.001
M	12	0.08	0.466	
N	22	-0.07	0.395	
H to I	14	0.49	2.294	0.05
J	4	0.03	0.152	
K	4	0.73	3.702	0.05
L	8	0.03	0.265	
M	4	0.58	2.779	0.05
N	14	0.43	1.436	
I to J	12	-0.46	1.578	
L	16	0.46	2.751	0.02
K	12	0.24	0.873	
M	12	0.09	0.306	
N	22	-0.06	0.299	
J to K	2	0.70	4.958	0.05
L	6	0	0	
M	2	0.55	3.056	
N	12	0.40	0.956	
K to L	6	-0.7	7.447	0.001
M	2	0.15	0.833	
N	12	-0.3	0.717	
L to M	6	0.55	5.107	0.01
N	16	0.40	1.677	
M to N	12	-0.15	0.357	

Appendix 3

Comparison of the groups of stands by pH(Sub. surface)
using t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	-0.22	1.401	0.01
H	5	-0.57	4.665	
I	13	-0.24	1.128	
J	3	-0.56	2.589	
K	3	-0.24	1.304	
L	7	0.61	2.349	
M	3	0.26	1.639	
N	13	-0.36	1.537	
G to H	14	-0.35	1.943	0.05
I	22	0.02	0.160	
J	12	-0.34	1.703	
K	12	-0.02	0.103	
L	16	-0.39	2.472	
M	12	0.48	2.529	
N	22	-0.14	1.046	
H to I	14	0.33	0.959	0.01
J	4	0.01	0.048	
K	4	0.33	2.115	
L	8	-0.04	0.180	
M	4	0.83	6.099	
N	14	0.21	1.038	
I to J	12	-0.32	1.201	
K	12	0	0	
L	16	-0.37	1.980	
M	12	0.50	1.928	
N	22	-0.12	0.796	
J to K	2	0.32	1.096	
L	6	-0.05	0.151	
M	2	0.82	3.107	
N	12	0.20	0.684	
K to L	6	-0.37	1.141	
M	2	0.5	2.326	
N	12	-0.12	0.416	
L to M	6	0.87	2.728	0.05
N	16	0.25	1.256	
M to N	12	-0.62	2.196	0.05

Appendix 4

Comparison of the groups of stands by pH(overall ave.)-
using t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	-0.24	1.391	
H	5	-0.64	4.097	0.01
I	13	-0.27	1.182	
J	3	-0.63	2.593	
K	3	-0.23	0.956	
L	7	-0.67	2.725	0.05
M	3	0.14	0.657	
N	13	-0.39	1.462	
G to H	14	-0.40	2.869	0.02
I	22	-0.03	0.231	
J	12	-0.39	1.954	
K	12	0.01	0.050	
L	16	-0.43	2.853	0.02
M	12	0.38	1.964	
N	22	-0.15	1.025	
H to I	14	0.37	1.904	
J	14	0.01	0.056	
K	4	0.41	2.319	
L	8	-0.03	0.068	
M	4	0.78	5.166	0.01
N	14	0.25	1.098	
I to J	12	-0.36	1.295	
K	12	0.04	0.144	
L	16	-0.40	2.146	0.05
M	12	0.41	1.499	
N	22	-0.12	0.727	
J to K	2	0.40	1.371	
L	6	-0.40	0.134	
M	2	0.77	3.080	
N	12	0.24	0.737	
K to L	6	-0.44	1.472	
M	2	0.37	1.504	
N	12	-0.16	0.492	
L to M	6	0.81	2.789	0.05
N	16	0.28	1.335	
M to N	12	0.53	1.646	

Appendix 5

Comparison of the groups of stands by conductivity
(surface) using t- test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	0.30	3.433	0.01
H	5	0.31	3.985	0.02
I	13	0.26	2.321	0.05
J	3	-0.10	0.773	
K	3	0.03	0.277	
L	7	-0.06	0.424	
M	3	0.22	2.033	
N	13	0.14	1.731	
G to H	14	0.01	0.142	
I	22	-0.04	0.620	
J	12	-0.4	3.884	0.01
K	12	0.27	2.738	0.02
L	16	-0.36	4.353	0.001
M	12	-0.08	0.812	
N	22	-0.16	3.053	0.01
H to I	14	-0.05	0.538	
J	4	-0.41	5.353	0.01
K	4	0.28	5.631	0.01
L	8	-0.37	3.231	0.02
M	4	-0.09	1.811	
N	14	-0.17	1.500	
I to J	12	-0.36	2.681	0.02
K	12	-0.23	1.757	
L	16	-0.32	3.330	0.01
M	12	-0.04	0.306	
N	22	-0.12	1.920	
J to K	2	0.13	1.250	
L	6	0.04	0.235	
M	2	0.32	3.071	
N	12	0.24	2.537	0.05
K to L	6	-0.09	0.549	
M	2	0.19	4.524	0.05
N	12	0.11	1.236	
L to M	6	0.28	1.706	
N	16	0.20	2.516	0.05
M to N	12	-0.08	0.892	

Appendix 6

Comparison of the groups of stands

by E.C.* (Sub surface) - t-test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	0.05	4.167	0.002
H	5	0.03	1.293	
I	13	0.03	1.345	
J	3	-0.07	1.759	
K	3	-0.03	0.833	
L	7	-0.06	1.083	
M	3	0	0	
N	13	-0.04	1.015	
G to H	14	-0.02	2.703	0.02
I	22	-0.02	2.000	
J	12	-0.12	9.302	
K	12	-0.08	7.273	
L	16	-0.11	4.365	
M	12	-0.05	3.876	
N	22	-0.09	4.813	
H to I	14	0	0	0.02
J	4	-0.10	3.966	
K	4	-0.06	2.765	
L	8	-0.09	1.957	
M	4	-0.03	1.172	
N	14	-0.07	2.108	
I to J	12	-0.10	3.774	0.01
K	12	-0.06	2.353	
L	16	-0.09	3.169	
M	12	-0.03	1.132	
N	22	-0.07	3.365	
J to K	2	0.04	0.943	
L	6	0.01	0.147	
M	2	0.07	1.461	
N	12	0.03	0.625	
K to L	6	-0.03	0.448	0.01
M	2	0.03	0.714	
N	12	-0.01	0.211	
L to M	6	0.06	0.882	
N	16	0.02	0.550	
M to N	12	-0.04	0.833	

*E.C. - Electrical Conductivity

Appendix 7

Comparison of the groups of stands by E.C (overall ave.)-
using t - test

Groups Compared	d.f.	$\bar{X}_1 \bar{X}_2$	t	p
D to G	13	0.08	1.072	
H	5	0.08	0.900	
I	13	0.05	0.607	
J	3	-0.08	0.496	
K	3	-0.03	0.201	
L	7	-0.06	0.442	
M	3	0.03	0.221	
N	13	-0.01	0.082	
G to H	14	0	0	
I	22	-0.03	0.669	
J	12	-0.16	1.894	
K	12	-0.11	1.375	
L	16	-0.14	2.009	
M	12	-0.05	0.655	
N	22	-0.09	2.083	0.05
H to I	14	-0.03	0.483	
J	4	-0.16	1.770	
K	4	0.11	1.486	
L	8	-0.14	1.345	
M	4	-0.05	0.904	
N	14	-0.07	1.541	
I to J	12	-0.13	1.370	
K	12	-0.08	0.879	
L	16	-0.11	1.489	
M	12	-0.02	0.230	
N	22	-0.06	0.929	
J to K	2	0.05	0.309	
L	6	0.02	0.125	
M	2	0.11	0.779	
N	12	0.07	0.778	
K to L	6	-0.03	0.194	
M	2	0.06	0.531	
N	12	0.02	0.233	
L to M	6	0.09	0.597	
N	16	0.05	0.695	
M to N	12	-0.04	0.315	

Appendix 8

Comparison of the groups of stands by
Ca (Surface) - t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	11.1	4.851	0.001
H	5	9.7	3.518	0.02
I	13	9.8	3.374	0.01
J	3	2.7	0.6805	
K	3	11.2	2.887	
L	7	2.4	0.482	
M	3	5.4	1.298	
N	13	7.5	1.515	
G to H	14	-1.4	0.814	
I	22	-1.3	0.832	
J	12	-8.4	3.542	0.01
K	12	0.1	0.043	
L	16	-8.7	4.565	0.001
M	12	-5.7	2.347	0.05
N	22	-3.6	1.442	
H to I	14	0.01	0.004	
J	4	-7.0	3.864	0.02
K	4	1.5	0.895	
L	8	-7.3	2.761	0.05
M	4	-4.3	2.065	
N	14	-2.2	0.529	
I to J	12	-7.1	2.193	0.05
K	12	1.4	0.435	
L	16	-7.4	3.247	0.01
M	12	-4.4	1.342	
N	22	-2.3	0.870	
J to K	2	8.5	4.71	0.05
L	6	-0.3	0.080	
M	2	2.7	0.998	
N	12	4.8	0.813	
K to L	6	-8.8	2.377	
M	2	-5.8	2.355	
N	12	-3.7	0.628	
L to M	6	3.0	0.785	
N	16	5.1	1.413	
M to N	12	2.1	0.355	

Appendix 9

Comparison of the groups of stands by Ca(Subsurface)

using the t- test

Groups Compared	d.f.:	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	3.94	2.253	0.05
H	5	2.16	1.840	
I	13	2.44	1.539	
J	3	-1.37	0.677	
K	3	1.82	1.001	
L	7	1.05	0.443	
M	3	3.19	1.839	
N	13	0.15	0.066	
G to H	14	-1.78	1.156	0.05
I	22	-1.50	1.402	
J	12	-5.31	2.559	
K	12	-2.12	1.039	
L	16	-2.89	1.873	
M	12	-0.75	0.368	
N	22	-3.79	2.842	
H to I	14	0.28	0.199	0.02
J	4	-3.53	1.867	
K	4	0.34	0.195	
L	8	-1.11	0.534	
M	4	1.03	0.595	
N	14	-2.01	1.012	
I to J	12	-3.81	2.043	
K	12	-0.62	0.339	
L	16	-1.39	0.956	
M	12	0.75	0.411	
N	22	-2.29	1.178	
J to K	2	3.19	2.018	
L	6	2.42	0.857	
M	2	4.56	2.960	
N	12	1.52	0.555	
K to L	6	-0.24	0.087	
M	2	1.37	1.411	
N	12	-0.24	0.089	
L to M	6	2.14	0.775	
N	16	-0.90	0.488	
M to N	12	-3.04	1.122	

Appendix 10

Comparison of the groups of stands by Ca (overall av.)

using t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	4.65	1.757	
H	5	3.62	1.117	
I	13	3.44	1.289	
J	3	-0.60	0.127	
K	3	3.65	0.840	
L	7	1.30	0.317	
M	3	3.60	0.743	
N	13	1.58	0.467	
G to H	14	-1.03	0.561	
I	22	-1.21	0.790	
J	12	-5.25	1.838	
K	12	1.0	0.364	
L	16	-3.35	1.491	
M	12	-1.05	0.363	
N	22	-3.07	1.673	
H to I	14	-0.18	0.087	
J	4	-4.22	1.554	
K	4	0.03	0.013	
L	8	-2.32	0.729	
M	4	-0.02	0.007	
N	14	-2.04	0.744	
I to J	12	-4.01	1.399	
K	12	0.21	0.076	
L	16	-2.14	1.239	
M	12	0.16	0.055	
N	22	-1.86	1.009	
J to K	2	4.25	1.447	
L	6	1.90	0.419	
M	2	4.20	1.022	
N	12	2.18	0.565	
K to L	6	-2.35	0.536	
M	2	-0.05	0.015	
N	12	-2.07	0.548	
L to M	6	2.3	0.502	
N	16	0.28	0.104	
M to N	12	-2.02	0.520	

Appendix 11

Comparison of the groups of stands by K (surface)
using t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	0.75	4.083	0.002
H	5	0.35	1.023	
I	13	0.52	1.778	
J	3	-0.25	0.500	
K	3	0.72	1.436	
L	7	0.08	0.130	
M	3	0.65	1.302	
N	13	0.16	0.363	
G to H	14	-0.40	5.044	0.001
I	22	-0.23	1.902	
J	12	-1.00	11.287	0.001
K	12	-0.03	0.333	
L	16	-0.67	2.507	0.05
M	12	-0.10	1.135	
N	22	-0.59	2.377	0.05
H to I	14	-0.17	0.803	0.02
J	4	-0.60	4.158	
K	4	0.37	2.500	
L	8	-0.27	0.556	
M	4	0.30	2.094	
N	14	-0.19	0.433	
I to J	12	-0.77	2.620	0.05
K	12	0.20	0.680	
L	16	-0.44	1.415	
M	12	0.13	0.443	
N	22	-0.36	1.325	
J to K	2	0.97	11.687	0.01
L	6	0.33	0.471	
M	2	0.90	15.901	0.001
N	12	0.41	0.658	
K to L	6	-0.64	0.913	0.899
M	2	0.07	0.897	
N	12	-0.56	0.899	
L to M	6	0.57	0.814	0.182
N	16	0.08	0.182	
M to N	12	-0.49	0.787	

Appendix 12

Comparison of the groups of stands by K (Sub surface)

using t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	0.22	1.577	
H	5	0.16	0.678	
I	13	-0.06	0.288	
J	3	-0.60	1.586	
K	3	0.26	0.739	
L	7	-0.06	0.128	
M	3	0.23	0.654	
N	13	0.26	0.592	
G to H	14	-0.06	0.719	
I	22	-0.28	3.057	0.01
J	12	-0.82	7.231	0.001
K	12	0.04	0.412	
L	16	-0.28	1.335	
M	12	0.01	0.103	
N	22	-0.43	2.297	0.05
H to I	14	-0.22	1.395	
J	4	-0.76	3.936	0.02
K	4	0.10	0.641	
L	8	-0.22	0.581	
M	4	0.07	0.447	
N	14	-0.42	1.140	
I to J	12	-0.54	2.430	0.05
K	12	0.32	1.493	
L	16	0	0	
M	12	0.29	1.352	
N	22	-0.20	0.900	
J to K	2	0.86	3.805	
L	6	0.54	0.982	
M	2	0.83	3.663	
N	12	0.34	0.647	
K to L	6	-0.32	0.589	
M	2	-0.03	0.234	
N	12	-0.52	0.996	
L to M	6	0.29	0.534	
N	16	-0.20	0.558	
M to N	12	-0.49	0.939	

Appendix 13

Comparison of the groups of stands by K(overall Ave.)

using t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	0.29	1.623	
H	5	0.20	0.599	
I	13	0.04	0.162	
J	3	-0.52	1.122	
K	3	0.35	0.792	
L	7	-0.03	0.057	
M	3	0.32	0.722	
N	13	-0.17	0.363	
G to H	14	-0.09	0.750	
I	22	-0.25	2.306	0.05
J	12	-0.81	5.645	0.001
K	12	0.06	0.457	
L	16	-0.32	1.365	
M	12	0.03	0.227	
N	22	-0.46	2.075	
H to I	14	-0.16	0.844	
J	4	-0.72	2.691	
K	4	0.15	0.620	
L	8	-0.23	0.540	
M	4	0.12	0.492	
N	14	-0.37	0.944	
I to J	12	-0.56	2.203	
K	12	0.31	1.253	
L	16	-0.07	0.266	
M	12	0.28	1.129	
N	22	-0.21	0.887	
J to K	2	0.87	3.385	
L	6	0.49	0.810	
M	2	0.84	3.227	
N	12	0.35	0.634	
K to L	6	-0.38	0.634	
M	2	-0.03	0.104	
N	12	-0.52	0.947	
L to M	6	0.35	0.584	
N	16	-0.14	0.366	
M to N	12	-0.49	0.892	

Appendix 14

Comparison of the groups of stands by Sodium (surface)

using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	0.06	1.626	
H	5	0.12	9.091	0.001
I	13	0.06	1.695	
J	3	0.10	7.143	0.01
K	3	0.14	8.235	0.01
L	7	0.11	1.528	
M	3	0.12	8.054	0.01
N	13	0.10	2.865	0.02
G to H	14	0.06	1.881	
I	22	0	0	
J	12	0.04	0.887	
K	12	0.08	1.778	
L	16	0.05	1.908	
M	12	0.06	1.327	
N	22	0.04	1.633	
H to I	14	-0.06	1.961	
J	4	-0.02	1.460	
K	4	0.02	1.282	
L	8	-0.01	0.763	
M	4	0	0	
N	14	-0.022	0.662	
I to J	12	0.04	0.924	
K	12	0.08	1.860	
L	16	0.05	1.984	
M	12	0.06	1.383	
N	22	0.04	1.667	
J to K	2	0.04	2.532	
L	6	0.01	0.536	
M	2	0.02	1.639	
N	12	0	0	
K to L	6	-0.03	1.875	
M	2	-0.02	1.156	
N	12	-0.04	0.936	
L to M	6	0.01	0.641	
N	16	-0.01	0.403	
M to N	12	-0.02	0.467	

Appendix 15

Comparison of the groups of stands by Sodium(Sub surface)
using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	0.09	2.507	0.05
H	5	0.13	5.078	0.01
I	13	0.06	1.068	
J	3	0.15	3.947	0.05
K	3	0.13	3.421	0.05
L	7	0.12	3.343	0.02
M	3	0.11	2.670	
N	13	0.12	3.604	0.01
G to H	14	0.04	1.370	
I	22	-0.03	0.962	
J	12	0.06	1.446	
K	12	0.04	0.966	
L	16	0.03	1.095	
M	12	0.02	0.476	
N	22	0.03	1.351	
H to I	14	-0.07	1.480	
J	4	0.02	1.639	
K	4	0	0	
L	8	-0.01	0.376	
M	4	-0.02	1.117	
N	14	-0.01	0.372	
I to J	12	0.09	1.335	
K	12	0.07	1.045	
L	16	0.06	1.471	
M	12	0.05	0.738	
N	22	0.06	1.967	
J to K	2	-0.02	1.639	
L	6	-0.03	0.783	
M	2	-0.04	1.569	
N	12	-0.03	0.780	
K to L	6	-0.01	0.263	
M	2	-0.02	0.816	
N	12	-0.01	0.262	
L to M	6	-0.01	0.253	
N	16	0	0	
M to N	12	0.01	0.258	

Appendix 16

Comparison of the groups of the stands by Sodium

(Overall av.) using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	0.08	2.222	0.05
H	5	0.12	5.063	0.01
I	13	0.06	1.177	
J	3	0.13	3.714	
K	3	0.13	3.714	0.05
L	7	0.11	3.344	0.02
M	3	0.10	2.604	
N	13	0.11	3.395	0.01
G to H	14	0.04	1.356	
I	22	-0.2	0.683	
J	12	0.05	1.188	
K	12	0.05	1.190	
L	16	0.03	1.225	
M	12	0.02	0.470	
N	22	0.03	1.351	
H to I	14	-0.06	1.395	
J	4	0.01	0.820	
K	4	0.01	0.775	
L	8	-0.01	0.407	
M	4	-0.02	1.117	
N	14	-0.01	0.379	
I to J	12	0.07	1.142	
K	12	0.07	1.142	
L	16	0.05	1.348	
M	12	0.04	0.649	
N	22	0.05	1.767	
J to K	2	0	0	
L	6	-0.02	0.567	
M	2	-0.03	1.177	
N	12	-0.02	0.535	
K to L	6	0.03	0.565	
M	2	-0.03	1.132	
N	12	-0.02	1.681	
L to M	6	-0.01	0.278	
N	16	0	0	
M to N	12	0.01	0.263	

Appendix 17

Comparison of the groups of stands by Manganese(surface)

using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	0.12	8.392	0.001
H	5	0.08	4.345	0.01
I	13	0.11	9.483	0.001
J	3	0.02	0.826	
K	3	-0.02	0.671	
L	7	0.04	1.312	
M	3	0.04	1.550	
N	13	-0.04	0.541	
G to H	14	-0.04	3.571	0.01
I	22	-0.01	1.409	
J	12	-0.10	6.757	0.001
K	12	-0.14	8.750	0.001
L	16	-0.08	5.161	0.001
M	12	-0.08	5.229	0.001
N	22	-0.16	4.420	0.001
H to I	14	0.03	3.488	0.01
J	4	-0.06	4.380	0.02
K	4	-0.10	5.000	0.02
L	8	-0.04	1.606	
M	4	-0.04	2.564	
N	14	-0.12	1.890	
I to J	12	-0.09	8.491	0.001
K	12	-0.13	10.000	0.001
L	16	-0.07	4.861	0.001
M	12	-0.07	6.250	0.001
N	22	-0.15	4.178	0.001
J to K	2	-0.04	1.600	
L	6	0.02	0.570	
M	2	0.02	1.265	
N	12	-0.06	0.660	
K to L	6	0.06	1.630	
M	2	0.06	2.430	
N	12	-0.02	0.220	
L to M	6	0	0	
N	16	-0.08	1.512	
M to N	12	-0.08	0.883	

Appendix 18

Comparison of the groups of stands by Manganese(sub-
surface) using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	0.02	2.899	0.02
H	5	0	0	
I	13	0.01	1.449	
J	3	0.01	0.909	
K	3	0	0	
L	7	-0.01	0.599	
M	3	-0.04	2.395	
N	13	-0.02	0.833	
G to H	14	-0.02	2.899	0.02
I	22	-0.01	2.439	0.05
J	12	-0.01	1.351	
K	12	-0.02	2.532	0.05
L	16	-0.03	3.571	0.01
M	12	-0.06	6.543	0.001
N	22	-0.04	3.361	0.01
H to I	14	0.01	1.449	
J	4	0.09	0.758	
K	4	0	0	
L	8	-0.01	0.662	
M	4	-0.04	2.381	
N	14	-0.02	0.952	
I to J	12	0	0	
K	12	-0.01	1.266	
L	16	-0.02	2.353	0.05
M	12	-0.05	5.495	0.001
N	22	-0.03	2.521	0.02
J to K	2	-0.01	0.735	
L	6	-0.02	1.010	
M	2	-0.05	2.825	
N	12	-0.03	3.371	0.01
K to L	6	-0.01	0.493	
M	2	-0.04	2.000	
N	12	-0.02	0.680	
L to M	6	-0.03	1.409	
N	16	-0.01	0.550	
M to N	12	0.02	0.673	

Appendix 19

Comparison of the groups of stands by Manganese
(overall av) using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	0.04	2.367	0.05
H	5	0.02	0.694	
I	13	0.03	1.899	
J	3	0.02	0.430	
K	3	0	0	
L	7	0	0	
M	3	-0.01	0.237	
N	13	-0.02	0.377	
G to H	14	-0.02	1.980	0.05
I	22	-0.01	1.563	
J	12	-0.02	1.220	
K	12	-0.04	2.174	
L	16	-0.04	2.963	
M	12	-0.05	3.546	
N	22	-0.06	2.353	
H to I	14	0.01	1.064	0.05
J	4	0	0	
K	4	-0.02	0.641	
L	8	-0.02	0.877	
M	4	-0.03	1.442	
N	14	-0.04	0.895	
I to J	12	-0.01	1.685	0.05
K	12	-0.03	1.775	
L	16	-0.03	2.326	
M	12	-0.04	3.306	
N	22	-0.05	1.976	
J to K	2	-0.02	0.368	0.05
L	6	-0.02	0.582	
N	12	-0.04	0.623	
K to L	6	0	0	0.05
M	2	-0.01	0.213	
N	12	-0.02	0.309	
L to M	6	-0.01	0.312	0.05
N	16	-0.02	0.531	
M to N	12	-0.01	0.157	0.05

Appendix 20

Comparison of the groups of stands by Magnesium (surface)
using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	2.84	3.992	0.002
H	5	2.33	2.467	
I	13	2.90	3.978	0.002
J	3	0.13	0.080	
K	3	2.77	2.054	
L	7	0.77	0.947	
M	3	0.37	0.273	
N	13	1.64	1.419	
G to H	14	-0.51	1.028	
I	22	0.06	0.157	
J	12	-2.71	3.531	0.01
K	12	-0.07	0.104	
L	16	-2.07	4.793	0.001
M	12	-2.47	3.675	0.01
N	22	-1.20	2.075	0.05
H to I	14	0.57	1.108	
J	4	-2.20	2.491	
K	4	0.44	0.971	
L	8	-1.56	3.509	0.01
M	4	-1.96	4.229	0.02
N	14	-0.69	0.743	
I to J	12	-2.77	3.492	0.01
K	12	-0.13	0.186	
L	16	-2.13	4.777	0.001
M	12	-2.53	3.615	0.01
N	22	-1.26	2.155	0.05
J to K	2	2.64	2.200	
L	6	0.64	0.813	
M	2	0.24	0.198	
N	12	1.51	1.111	
K to L	6	-2.00	3.650	0.02
M	2	-2.40	1.500	
N	12	-1.13	0.865	
L to M	6	-0.40	0.723	
N	12	0.87	0.642	
M to N	12	1.27	0.972	

Appendix 21

Comparison of the groups of stands by Magnesium (sub-
surface) using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	0.88	1.952	
H	5	0.20	0.339	
I	13	0.14	0.241	
J	3	-2.43	4.758	0.02
K	3	-1.10	1.846	
L	7	-0.57	0.781	
M	3	-0.07	0.135	
N	13	-1.25	1.495	
G to H	14	-0.68	1.580	
I	22	-0.74	2.170	0.05
J	12	-3.31	6.267	0.001
K	14	-1.98	3.640	0.002
L	16	-1.45	3.313	0.01
M	12	-0.95	1.793	
N	22	-2.13	4.744	0.001
H to I	14	-0.06	0.112	
J	4	-2.63	3.942	0.02
K	4	-1.30	1.821	
L	8	-0.77	1.131	
M	4	-0.27	0.402	
N	14	-1.45	1.949	
I to J	12	-2.57	3.696	0.01
K	12	-1.24	1.753	
L	16	-0.71	1.400	
M	12	-0.21	0.301	
N	22	-1.39	2.877	0.01
J to K	2	1.33	2.285	
L	6	1.86	2.131	
M	2	2.36	5.472	0.05
N	12	1.18	1.162	
K to L	6	0.53	0.592	
M	2	1.03	1.722	
N	12	-0.15	0.146	
L to M	6	0.50	0.571	
N	16	-0.68	1.033	
M to N	12	-1.18	1.161	

Appendix 22

Comparison of the groups of stands by Magnesium
(overall av.) using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	1.12	1.668	
H	5	0.62	0.696	
I	13	0.66	0.976	
J	3	-1.92	1.637	
K	3	-0.33	0.281	
L	7	-0.30	0.315	
M	3	0.01	0.008	
N	13	-0.68	0.720	
G to H	14	-0.50	1.005	
I	22	-0.46	1.200	
J	12	-3.04	4.338	0.001
K	12	-1.45	2.068	
L	16	-1.42	3.295	0.01
M	12	-1.11	1.519	
N	22	-1.80	3.602	0.002
H to I	14	0.04	0.074	
J	4	-2.54	3.477	0.05
K	4	-0.95	1.298	
L	8	-0.92	1.240	
M	4	-0.61	0.729	
N	14	-1.30	1.661	
I to J	12	-2.58	3.646	0.01
K	12	-0.99	1.398	
L	16	-0.96	1.809	
M	12	0.65	0.881	
N	22	-1.34	2.674	0.02
J to K	2	1.59	2.243	
L	6	1.62	1.646	
M	2	1.93	1.991	
N	12	1.24	1.152	
K to L	6	0.03	0.030	
M	2	0.34	0.349	
N	12	-0.35	0.325	
L to M	6	0.31	0.300	
N	16	-0.38	0.541	
M to N	12	-0.69	0.629	

Appendix 23

Comparison of the groups of stands by Sand (surface)

using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	-2.70	1.341	
H	5	-5.08	0.725	
I	13	-2.81	1.428	
J	3	1.00	0.221	
K	3	4.99	1.183	
L	7	-0.42	0.096	
M	3	1.48	0.374	
N	13	4.08	1.071	
G to H	14	-2.38	1.554	
I	22	0.11	0.109	
J	12	3.70	1.784	
K	12	7.69	3.936	0.002
L	16	2.28	1.080	
M	12	4.18	2.251	0.05
N	22	6.78	3.603	0.002
H to I	14	2.27	1.526	
J	4	6.08	2.069	
K	4	10.69	3.867	0.02
L	8	4.66	1.311	
M	4	6.56	2.835	0.05
N	14	9.16	2.879	0.02
I to J	12	3.81	1.898	
K	12	7.80	4.142	0.002
L	16	2.39	1.144	
M	12	4.29	2.407	0.05
N	22	6.89	3.685	0.002
J to K	2	3.99	1.105	
L	6	-1.42	0.279	
M	2	0.48	0.158	
N	12	3.08	0.686	
K to L	6	6.00	1.206	
M	2	-3.51	1.695	
N	12	-0.91	0.205	
L to M	6	1.90	0.389	
N	16	4.50	1.456	
M to N	12	2.60	0.591	

Appendix 24

Comparison of the groups of stands by Sand (sub surface)
using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	-9.07	1.786	
H	5	-1.32	0.177	
I	13	-3.69	0.557	
J	3	9.12	1.361	
K	3	7.02	1.028	
L	7	6.02	1.246	
M	3	5.62	0.802	
N	13	6.62	1.520	
G to H	14	7.75	1.608	
I	22	5.38	1.432	
J	12	18.19	3.181	0.01
K	12	16.09	2.832	0.02
L	16	15.09	4.208	0.001
M	12	14.69	2.568	0.05
N	22	15.69	5.467	0.001
H to I	14	-2.37	0.392	
J	4	10.44	1.295	
K	4	8.34	1.047	
L	8	7.34	1.442	
M	4	6.94	0.860	
N	14	7.94	1.864	
I to J	12	12.81	1.653	
K	12	10.71	1.386	
L	16	9.71	2.088	
M	12	9.31	1.208	
N	22	10.31	2.916	0.01
J to K	2	-2.10	0.500	
L	6	-3.10	0.667	
M	2	-3.50	0.743	
N	12	-2.50	0.529	
K to L	6	-1.00	0.220	
M	2	-1.40	0.331	
N	12	-0.40	0.085	
L to M	6	-0.40	0.086	
N	16	0.60	0.124	
M to N	12	1.00	0.212	

Appendix 25

Comparison of the groups of stands by Sand (overall av.)

using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	-8.16	1.805	
H	5	-1.94	0.251	
I	13	-4.24	0.679	
J	3	7.66	0.955	
K	3	6.72	0.923	
L	7	4.86	0.773	
M	3	4.96	0.654	
N	3	6.26	1.190	
G to H	14	6.22	1.386	
I	22	3.92	1.146	
J	12	15.82	3.025	0.02
K	12	14.88	2.956	0.02
L	16	13.02	3.500	0.01
M	12	13.12	2.568	0.05
N	22	14.42	4.794	0.001
H to I	14	-2.30	0.395	
J	4	9.60	1.063	
K	4	8.66	1.007	
L	8	6.80	1.083	
M	4	6.90	0.786	
N	14	8.20	1.627	
I to J	12	11.90	1.597	
K	12	10.96	1.498	
L	16	9.10	1.904	
M	12	9.20	1.248	
N	22	10.50	2.861	0.01
J to K	2	-0.04	0.124	
L	6	-2.80	0.385	
M	2	-2.70	0.333	
N	12	-1.40	0.226	
K to L	6	-1.86	0.267	
M	2	-1.76	0.261	
N	12	-0.46	0.076	
L to M	6	0.10	0.014	
N	16	1.40	0.336	
M to N	12	1.30	0.214	

Appendix 26

Comparison of the groups of stands by Clay (surface)

using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	-0.08	0.089	
H	5	-0.06	0.049	
I	13	0.15	0.255	
J	3	-0.18	4.368	0.02
K	3	0.16	0.112	
L	7	-5.86	1.651	
M	3	-4.00	1.549	
N	13	-7.78	2.761	0.02
G to H	14	0.02	0.025	
I	22	0.23	0.539	
J	12	-8.10	7.226	0.001
K	12	0.24	0.248	
L	16	-5.78	3.634	0.01
M	12	-3.92	2.915	0.02
N	22	-7.70	5.475	0.001
H to I	14	0.21	0.400	
J	4	-8.12	5.125	0.01
K	4	0.22	0.178	
L	8	-5.80	2.019	
M	4	-3.94	1.828	
N	14	-7.72	3.174	0.01
I to J	12	-8.33	8.165	0.001
K	12	0.01	0.018	
L	16	-6.01	3.959	0.002
M	12	-4.15	3.940	0.002
N	22	-7.93	5.803	0.001
J to K	2	8.34	4.162	0.02
L	6	2.32	0.596	
M	2	4.18	1.191	
N	12	0.40	0.115	
K to L	6	-6.02	1.505	
M	2	-4.16	1.335	
N	12	7.94	2.309	0.05
L to M	6	1.86	0.440	
N	16	-1.92	0.784	
M to N	12	-3.78	1.064	

Appendix 27

Comparison of the groups of stands by Clay (sub surface)

using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	4.59	0.981	
H	5	-0.33	0.046	
I	13	3.70	0.696	
J	3	-20.35	2.560	
K	3	-5.79	0.739	
L	7	-12.11	2.171	
M	3	-7.21	0.835	
N	13	-13.51	2.242	0.05
G to H	14	-4.92	1.161	
I	22	-0.80	0.265	
J	12	24.94	4.832	0.001
K	12	-10.58	2.033	
L	16	-16.70	4.859	0.001
M	12	-11.80	2.206	0.05
N	22	-18.10	5.455	0.001
H to I	14	4.03	0.847	
J	4	-20.02	2.680	
K	4	-5.66	0.747	
L	8	-11.78	2.296	
M	4	-6.11	0.864	
N	14	-13.18	2.460	0.05
I to J	12	-24.05	3.996	0.002
K	12	-9.69	1.599	
L	16	15.81	4.107	0.001
M	12	-10.91	1.765	
N	22	-17.21	4.866	0.001
J to K	2	14.36	2.023	
L	6	8.24	1.428	
M	2	13.14	1.614	
N	12	6.84	0.982	
K to L	6	-3.08	0.526	
M	2	-1.22	0.145	
N	22	-7.57	1.075	
L to M	6	4.90	0.797	
N	16	-1.40	0.323	
M to N	12	-6.30	0.887	

Appendix 28

Comparison of the groups of stands by Clay (overall av.)

using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	4.55	1.007	
H	5	-0.37	0.037	
I	13	3.43	0.665	
J	3	-17.88	1.888	
K	3	-4.75	0.534	
L	7	-10.88	1.572	
M	3	-6.58	0.727	
N	13	-12.48	1.793	
G to H	14	-4.82	1.167	
I	22	-1.12	0.389	
J	12	-22.43	4.208	0.002
K	12	-9.30	1.806	
L	16	-15.43	4.046	0.001
M	12	-11.13	2.140	
N	22	-17.03	4.640	0.001
H to I	14	3.70	0.795	
J	4	-17.61	2.027	
K	4	-4.48	0.541	
L	8	-10.61	1.698	
M	4	-6.31	0.752	
N	14	-12.21	1.982	
I to J	12	-21.31	3.467	0.01
K	12	-8.18	1.364	
L	16	-14.51	3.415	0.01
M	12	-10.01	1.658	
N	22	15.91	4.122	0.001
J to K	2	13.13	1.218	
L	6	7.00	0.846	
M	2	11.30	1.027	
N	12	5.40	0.641	
K to L	6	-6.13	0.764	
M	2	-1.63	0.181	
N	12	-7.73	0.929	
L to M	6	4.30	0.532	
N	16	-1.60	0.301	
M to N	12	-5.90	0.707	

Appendix 29

Comparison of the groups of stands by Silt (surface)
using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	2.78	1.781	
H	5	5.14	2.281	
I	13	2.66	1.685	
J	3	7.18	2.339	
K	3	-5.15	1.504	
L	7	5.28	1.661	
M	3	2.52	0.771	
N	13	3.70	1.579	
G to H	14	2.36	1.861	
I	22	-0.12	0.137	
J	12	4.40	2.747	0.02
K	12	-7.93	4.420	0.001
L	16	2.50	1.555	
M	12	-0.26	0.149	
N	22	0.92	0.756	
H to I	14	-2.48	1.930	
J	4	2.04	1.046	
K	4	10.29	4.089	0.02
L	8	0.14	0.053	
M	4	-2.62	1.104	
N	14	-1.44	0.731	
I to J	12	4.52	2.775	0.02
K	12	7.81	4.294	0.002
L	16	2.62	1.620	
M	12	-0.14	0.179	
N	22	1.04	0.851	
J to K	2	-12.33	3.998	
L	6	-1.90	0.524	
M	2	-4.66	1.686	
N	12	-3.48	1.297	
K to L	6	10.43	2.725	0.05
M	2	7.67	2.024	
N	12	8.85	3.157	0.01
L to M	6	-2.78	0.732	
N	16	-1.58	0.783	
M to N	12	1.18	0.426	

Appendix 30

Comparison of the groups of stands by Silt (sub surface)

using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	4.48	1.926	
H	5	1.65	0.432	
I	13	-0.01	0.003	
J	3	11.23	2.221	
K	3	-1.03	0.176	
L	7	6.09	1.994	
M	3	1.59	0.271	
N	13	6.89	2.027	
G to H	14	-2.83	1.654	
I	22	-4.49	2.466	0.05
J	12	6.75	3.230	0.01
K	12	-5.51	2.270	0.05
L	16	1.61	1.134	
M	12	-2.89	1.188	
N	22	2.41	1.462	
H to I	14	-1.66	0.543	
J	4	9.58	0.953	
K	4	-2.68	0.702	
L	8	4.44	2.114	
M	4	-0.06	0.016	
N	14	5.24	1.912	
I to J	12	11.24	2.683	0.02
K	12	0.92	0.234	
L	16	6.100	2.441	0.05
M	12	1.60	0.366	
N	22	6.90	3.165	0.01
J to K	2	-12.26	2.597	
L	6	-5.14	2.144	
M	2	-9.64	2.030	
N	12	-4.34	1.171	
K to L	6	7.12	2.344	
M	2	2.62	0.424	
N	12	7.92	2.028	
L to M	6	-4.50	1.475	
N	16	0.80	0.357	
M to N	12	5.30	1.356	

Appendix 31

Comparison of the groups of stands by Silt (overall av.)

using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	3.61	1.571	
H	5	2.21	0.625	
I	13	0.81	0.247	
J	3	10.22	2.143	
K	3	-1.97	0.366	
L	7	6.02	1.987	
M	3	1.62	0.303	
N	13	6.22	1.846	
G to H	14	-1.46	0.796	
I	22	-2.80	1.701	
J	12	6.61	2.942	0.02
K	12	-5.58	2.220	0.05
L	16	2.41	1.574	
M	12	-1.99	0.809	
N	22	2.61	1.547	
H to I	14	-1.40	0.523	
J	4	8.01	2.694	
K	4	-4.18	1.129	
L	8	3.81	1.732	
M	4	-0.59	0.165	
N	14	4.01	0.455	
I to J	12	9.41	2.571	0.05
K	12	-2.78	0.727	
L	16	5.21	2.320	0.05
M	12	0.81	0.214	
N	22	5.41	2.659	0.02
J to K	2	12.19	2.510	
L	6	-4.20	1.537	
M	2	-8.60	1.878	
N	12	-4.00	1.060	
K to L	6	7.99	2.482	0.05
M	2	3.59	0.616	
N	12	8.19	2.080	
L to M	6	-4.40	1.408	
N	16	0.20	0.087	
M to N	12	4.60	1.178	

Appendix 32

Comparison of the groups of stands
by Soil Colour Hue (surface) - by using t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	-1.46	2.592	0.05
H	5	0.20	0.197	
I	13	-1.46	2.592	0.05
J	3	3.33	1.547	
K	3	2.03	1.462	
L	7	1.66	1.243	
M	3	3.33	3.095	
N	13	2.50	2.063	
G to H	14	1.66	8.333	0.01
I	22	0	0	
J	12	4.79	5.088	0.001
K	12	3.54	5.396	0.001
L	16	3.12	4.845	0.001
M	12	4.79	9.072	0.001
N	22	3.96	6.611	0.001
H to I	14	-1.66	3.333	0.01
J	4	3.13	1.744	
K	4	1.88	1.554	
L	8	1.46	1.266	
M	4	3.13	3.338	0.05
N	14	2.30	2.188	0.05
I to J	12	4.79	5.088	0.001
K	12	3.54	2.433	0.05
L	16	3.12	4.845	0.001
M	12	4.79	9.072	0.001
N	22	3.96	6.611	0.001
J to K	2	-1.25	0.447	
L	6	-1.67	0.868	
M	2	0	0	
N	12	-0.83	0.540	
K to L	6	-0.42	0.257	
M	2	1.25	0	
N	12	0.43	0.285	
L to M	6	1.67	1.097	
N	16	0.84	1.471	
M to N	12	-0.83	0.583	

Appendix 33

Comparison of the groups of stands
by Soil Colour Hue (sub surface) - using the t-test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	-1.36	2.305	0.05
H	5	0.83	1.388	
I	13	-1.09	1.533	
J	3	4.58	3.959	0.05
K	3	3.33	3.631	0.05
L	7	2.80	1.914	
M	3	3.02	2.935	
N	13	3.59	2.671	0.02
G to H	14	2.19	5.069	0.001
I	22	0.27	0.684	
J	12	5.94	8.680	0.001
K	12	4.69	7.589	0.001
L	16	3.86	5.770	0.001
M	12	4.38	6.763	0.001
N	22	4.95	7.270	0.001
H to I	14	-1.92	3.481	0.01
J	4	3.75	6.477	0.01
K	4	2.14	2.140	
L	8	1.67	1.603	
M	4	2.19	5.718	0.01
N	14	2.76	2.449	0.05
I to J	12	5.67	6.752	0.001
K	12	4.42	5.623	0.001
L	16	3.59	4.960	0.001
M	12	4.11	5.074	0.001
N	22	4.68	6.820	0.001
J to K	2	-1.25	1.322	
L	6	-2.08	1.311	
M	2	-1.56	1.377	
N	12	-0.99	0.605	
K to L	6	-0.83	0.545	
M	2	0.37	0.496	
N	12	0.26	0.161	
L to M	6	0.52	0.335	
N	16	1.09	1.012	
M to N	12	0.57	0.351	

Appendix 34

Comparison of the groups of stands
by Soil Colour Hue (overall av.) - using the t-test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	-1.39	2.460	0.05
H	5	0.70	1.036	
I	13	-1.19	1.787	
J	3	4.33	3.346	0.05
K	3	3.08	3.080	
L	7	2.33	1.792	
M	3	3.08	3.080	
N	13	3.37	2.530	0.05
G to H	14	2.09	4.816	0.001
I	22	0.20	0.543	
J	12	5.72	8.183	0.001
K	12	4.47	7.352	0.001
L	16	3.72	5.653	0.001
M	12	4.47	7.352	0.001
N	22	4.76	7.094	0.001
H to I	14	-1.89	7.566	0.01
J	4	3.63	4.197	0.02
K	4	2.38	4.391	0.02
L	8	1.63	1.538	
M	4	2.38	4.391	0.02
N	14	2.67	2.369	0.05
I to J	12	5.52	6.715	0.001
K	12	4.27	5.716	0.001
L	16	3.52	5.014	0.001
M	12	4.27	5.716	0.001
N	22	4.56	7.331	0.001
J to K	2	-1.25	0.922	
L	6	-2.00	1.232	
M	2	-1.25	0.921	
N	12	-0.96	0.585	
K to L	6	-0.75	0.487	
M	2	0	0	
N	12	0.29	0.191	
L to M	6	0.75	0.487	
N	16	1.04	0.973	
M to N	12	0.29	0.208	

Appendix 35

Comparison of the groups of stands by Altitude

using the t - test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	-412.5	5.643	0.001
H	5	30.0	0.457	
I	13	-255.0	2.021	
J	3	547.5	10.156	0.01
K	3	457.5	2.390	
L	7	367.5	3.757	0.01
M	3	277.5	5.147	0.02
N	13	495.0	4.837	0.001
G to H	14	442.5	6.656	0.001
I	22	157.5	2.254	0.05
J	12	960.0	10.944	0.001
K	12	870.0	7.450	0.001
L	16	780.0	11.755	0.001
M	12	690.0	7.866	0.001
N	22	907.5	15.138	0.001
H to I	14	-285.0	2.572	0.05
J	4	517.5	6.975	0.01
K	4	427.5	2.542	
L	8	337.5	3.782	0.01
M	4	247.5	3.336	0.05
N	14	465.0	5.126	0.001
I to J	12	802.5	5.208	0.001
K	12	712.5	4.138	0.002
L	16	622.5	6.366	0.001
M	12	532.5	3.456	0.01
N	22	750.0	9.608	0.001
J to K	2	-90.0	0.362	
L	6	-180.0	1.524	
M	2	-270.0	8.485	0.02
N	12	-52.5	0.422	
K to L	6	-90.0	0.543	
M	2	-180.0	0.724	
N	12	37.5	0.256	
L to M	6	-90.0	0.762	
N	16	127.5	1.535	
M to N	12	217.5	1.749	

Appendix 36

Comparison of the groups of stands by Slope
using the t- test

Groups Compared	d.f.	$\bar{X}_1 - \bar{X}_2$	t	p
D to G	13	-1.26	0.197	
H	5	6.66	0.891	
I	13	3.99	0.516	
J	3	9.66	0.859	
K	3	12.66	1.108	
L	7	7.33	1.145	
M	3	5.66	0.420	
N	13	12.33	2.408	0.05
G to H	14	7.92	1.764	
I	22	5.25	1.277	
J	12	10.92	1.727	
K	12	13.92	2.180	0.05
L	16	8.59	2.239	0.05
M	12	0.92	0.982	
N	22	13.59	4.532	0.001
H to I	14	-2.67	0.457	
J	4	3.00	1.309	
K	4	6.00	2.089	
L	8	0.67	0.242	
M	4	-1.00	0.154	
N	14	5.67	1.854	
I to J	12	5.67	0.684	
K	12	8.67	1.040	
L	16	3.34	0.705	
M	12	1.67	0.189	
N	22	8.34	2.273	0.05
J to K	2	3.00	0.949	
L	6	-2.33	0.629	
M	2	-4.00	0.398	
N	12	2.67	0.631	
K to L	6	-5.33	1.353	
M	2	-7.00	0.670	
N	12	-0.33	0.076	
L to M	6	-1.67	0.280	
N	16	5.00	1.811	
M to N	12	6.67	1.271	

Appendix 37

pH of the Soil Samples at Various Depths

Stand Number	<u>Depth in Centimeters</u>				
	<u>0 - 10</u>	<u>20 - 30</u>	<u>40 - 50</u>	<u>60 - 70</u>	<u>80 - 90</u>
1	5.1	5.6	5.8	5.9	6.0
2	5.9	5.8	5.8	5.9	6.0
3	5.8	5.9	6.1	6.1	6.1
4	5.7	5.7	5.5	5.6	5.7
5	5.8	5.9	5.6	5.6	5.6
6	6.1	6.6	6.8	6.4	6.8
7	6.3	6.5	6.8	6.2	6.2
8	5.8	5.8	5.6	6.0	5.9
9	5.9	6.0	5.8	5.6	5.5
10	5.7	5.8	5.6	5.5	5.2
11	4.5	5.8	6.3	6.4	5.9
12	5.3	5.3	5.5	5.4	5.5
13	5.6	5.7	5.8	5.8	5.8
14	5.8	5.5	5.5	5.5	5.8
15	5.8	5.5	5.8	5.9	6.0
16	5.9	5.9	5.9	5.9	6.0
17	6.0	6.1	6.0	6.0	5.8
18	6.2	6.2	6.3	6.2	6.0
19	6.0	6.2	6.3	6.2	NA
20	5.8	5.6	6.0	6.0	6.0

NA - Not augerable because bedrock . was reached.

Appendix 37
(Cont'd)

Stand Number	<u>Depth in Centimeters</u>				
	<u>0 - 10</u>	<u>20 - 30</u>	<u>40 - 50</u>	<u>60 - 70</u>	<u>80 - 90</u>
21	5.9	6.0	5.8	5.7	5.7
22	5.8	5.9	5.9	NA	NA
23	5.8	5.6	NA	NA	NA
24	5.6	5.7	5.8	5.8	NA
25	5.6	5.9	5.9	5.8	NA
26	5.5	5.7	5.6	NA	NA
27	5.4	5.7	NA	NA	NA
28	5.7	5.8	5.8	NA	NA
29	5.3	NA	NA	NA	NA
30	5.2	5.4	NA	NA	NA
32	4.4	5.0	5.3	5.2	5.6
33	5.2	5.7	5.5	5.5	5.5
34	6.0	6.2	5.8	5.7	5.9
35	6.0	6.4	6.2	6.3	6.0
36	5.9	6.3	6.5	6.5	6.3
37	5.6	5.7	5.7	5.7	5.6
38	5.6	5.9	6.0	5.7	5.8
39	5.9	5.8	5.7	5.5	5.5
40	5.1	5.4	5.5	5.2	5.2
41	5.2	5.5	5.2	5.2	5.0

Appendix 37
(Cont'd)

<u>Depth in Centimeters</u>					
<u>Stand</u>					
<u>Number</u>	<u>0 - 10</u>	<u>20 - 30</u>	<u>40 - 50</u>	<u>60 - 70</u>	<u>80 - 90</u>
42	5.5	5.0	5.0	5.0	5.1
43	5.3	5.3	5.0	5.1	5.1
44	5.4	5.5	5.1	5.2	5.4
45	5.0	5.2	5.4	5.4	5.2
46	4.7	5.2	5.3	5.3	5.5
47	4.9	5.0	4.9	5.1	5.0
48	5.0	5.1	5.6	5.5	5.4
49	5.3	5.7	5.5	5.3	5.3
50	5.3	5.2	5.4	NA	NA
51	5.2	5.7	5.6	5.4	5.5
52	5.6	5.8	5.8	5.9	NA
53	5.5	5.5	5.4	5.0	5.5
54	5.4	5.3	5.1	5.6	NA
55	5.0	5.2	5.5	5.5	NA
56	5.0	5.1	5.7	5.3	NA
57	5.1	NA	NA	NA	NA
58	5.6	5.5	5.3	NA	NA
59	5.0	NA	NA	NA	NA
60	4.9	4.9	NA	NA	NA
61	5.2	5.5	5.6	NA	NA

Appendix 38

Electrical Conductivity of the Soil Samples
at Various Depths in mmhos/cm

Stand Number	<u>Depth in Centimeters</u>				
	<u>0 - 10</u>	<u>20 - 30</u>	<u>40 - 50</u>	<u>60 - 70</u>	<u>80 - 90</u>
1	0.477	0.166	0.10	0.12	0.10
2	0.26	0.18	0.09	0.09	0.07
3	0.28	0.18	0.12	0.08	0.08
4	0.20	0.15	0.11	0.08	0.07
5	0.47	0.22	0.18	0.11	0.09
6	0.49	0.17	0.08	0.07	0.07
7	0.28	0.12	0.10	0.12	0.10
8	0.44	0.10	0.11	0.06	0.04
9	0.41	0.34	0.21	0.11	0.09
10	0.21	0.23	0.13	0.10	0.09
11	0.26	0.31	0.24	0.20	0.24
12	0.41	0.19	0.08	0.10	0.15
13	0.11	0.04	0.04	0.05	0.07
14	0.72	0.20	0.06	0.07	0.10
15	0.31	0.14	0.09	0.08	0.06
16	0.23	0.12	0.08	0.07	0.05
17	0.18	0.05	0.05	0.05	0.07
18	0.10	0.06	0.06	0.05	0.04
19	0.59	0.05	0.05	0.04	NA
20	0.28	0.14	0.06	0.06	0.06

Appendix 38
(Cont'd)

Stand Number	Depth in Centimeters				
	0 -- 10	20 -- 30	40 -- 50	60 -- 70	80 -- 90
21	0.10	0.04	0.04	0.03	0.03
22	0.17	0.05	0.04	NA	NA
23	0.07	0.10	NA	NA	NA
24	0.11	0.05	0.04	0.04	NA
25	0.16	0.04	0.05	0.05	NA
26	0.16	0.06	0.06	NA	NA
27	0.31	0.03	NA	NA	NA
28	0.06	0.03	0.02	NA	NA
29	0.36	NA	NA	NA	NA
30	0.49	0.13	NA	NA	NA
32	0.18	0.12	0.10	0.12	0.10
33	0.49	0.25	0.15	0.11	0.08
34	0.39	0.17	0.14	0.13	0.07
35	0.67	0.22	0.17	0.18	0.13
36	0.62	0.34	0.22	0.31	0.16
37	0.36	0.09	0.05	0.04	0.04
38	0.52	0.28	0.20	0.20	0.17
39	0.93	0.24	0.11	0.13	0.12
40	0.26	0.10	0.07	0.08	0.07
41	0.22	0.08	0.06	0.06	0.06

Appendix 38
(Cont'd)

Stand Number	Depth in Centimeters				
	0 - 10	20 - 30	40 - 50	60 - 70	80 - 90
42	0.23	0.20	0.12	0.07	0.10
43	0.50	0.20	0.11	0.09	0.10
44	0.67	0.28	0.12	0.10	0.09
45	0.54	0.12	0.07	0.10	0.09
46	0.31	0.07	0.06	0.08	0.04
47	0.36	0.14	0.08	0.04	0.02
48	0.54	0.12	0.09	0.06	0.07
49	0.57	0.20	0.09	0.07	0.07
50	0.22	0.15	0.08	NA	NA
51	0.12	0.04	0.06	0.05	0.04
52	0.10	0.03	0.03	0.03	NA
53	0.06	0.04	0.03	0.03	0.03
54	0.09	0.08	0.07	0.04	NA
55	0.06	0.04	0.04	0.05	NA
56	0.09	0.05	0.03	0.03	NA
57	0.08	NA	NA	NA	NA
58	0.09	0.04	0.04	NA	NA
59	0.16	NA	NA	NA	NA
60	0.14	0.05	NA	NA	NA
61	0.06	0.03	0.02	NA	NA

Appendix 39

Calcium Contents of the Soil Samples at Various Depths
in meq/100gm

<u>Stand</u> <u>Number</u>	<u>Depth in Centimeters</u>				
	<u>0 - 10</u>	<u>20 - 30</u>	<u>40 - 50</u>	<u>60 - 70</u>	<u>80 - 90</u>
1	9.0	8.0	8.0	9.0	7.0
2	10.0	6.0	7.0	8.0	5.0
3	7.0	9.0	8.0	7.0	8.0
4	11.0	6.0	6.0	7.0	3.0
5	20.0	14.0	11.0	10.0	10.0
6	23.0	13.0	8.0	8.0	8.0
7	15.0	10.0	9.0	8.0	9.0
8	14.0	4.0	5.0	2.0	1.0
9	12.0	7.0	9.0	7.0	7.0
10	34.0	21.0	12.5	7.5	7.0
11	7.0	17.0	15.0	9.5	6.0
12	11.0	7.5	6.0	6.0	7.0
13	9.0	4.5	4.5	6.5	7.5
14	30.0	5.0	4.0	6.0	7.0
15	20.0	6.5	7.0	7.0	7.5
16	11.0	6.0	6.5	5.0	7.0
17	12.0	6.0	5.0	10.5	12.5
18	14.0	10.0	7.0	7.0	6.0
19	23.5	9.5	8.5	6.0	NA
20	10.5	11.5	6.0	6.0	5.5

Appendix 39
(Cont'd)

<u>Stand Number</u>	<u>Depth in Centimeters</u>				
	<u>0 - 10</u>	<u>20 - 30</u>	<u>40 - 50</u>	<u>60 - 70</u>	<u>80 - 90</u>
21	8.0	3.5	4.5	3.5	4.0
22	11.0	5.0	5.5	NA	NA
23	13.0	5.0	NA	NA	NA
24	7.0	3.5	3.5	4.5	NA
25	7.0	4.0	3.0	2.0	NA
26	10.0	4.5	4.0	NA	NA
27	10.5	3.5	NA	NA	NA
28	7.0	5.0	2.5	NA	NA
29	14.5	NA	NA	NA	NA
30	17.0	10.0	NA	NA	NA
32	3.0	6.0	8.0	8.0	17.0
33	13.5	14.5	16.0	9.0	8.0
34	22.0	12.5	9.5	8.5	8.5
35	17.0	12.5	10.0	8.5	8.0
36	19.5	17.0	15.0	12.5	10.0
37	13.0	7.5	5.0	4.0	5.0
38	15.5	11.5	12.0	12.5	7.5
39	24.5	8.5	6.0	11.0	7.0
40	13.5	8.0	7.0	7.0	7.5
41	13.5	7.5	6.0	5.0	6.0

Appendix 39
(Cont'd)

Stand Number	Depth in Centimeters				
	0 - 10	20 - 30	40 - 50	60 - 70	80 - 90
42	18.0	7.0	5.5	5.0	5.5
43	13.0	9.0	4.0	4.5	6.5
44	21.5	12.5	5.0	5.5	5.5
45	11.5	6.0	7.0	5.0	7.0
46	17.5	9.0	9.0	9.5	7.5
47	16.0	10.5	6.0	6.0	5.0
48	19.0	10.0	11.0	7.0	11.0
49	27.0	14.5	8.0	7.0	6.0
50	14.0	10.0	8.0	NA	NA
51	12.0	7.0	11.0	11.0	5.0
52	9.0	6.0	4.0	7.0	NA
53	11.0	15.0	8.0	5.0	5.0
54	9.0	10.0	6.0	NA	NA
55	6.0	7.0	4.5	6.0	NA
56	7.0	3.5	5.0	3.0	NA
57	12.0	NA	NA	NA	NA
58	10.0	5.0	5.0	NA	NA
59	9.0	NA	NA	NA	NA
60	8.0	2.0	NA	NA	NA
61	7.0	9.0	6.0	NA	NA

Appendix 40

Sodium Contents of the Soil Samples at Various Depths

in meq/100gm

<u>Stand</u> <u>Number</u>	<u>Depth in Centimeters</u>				
	<u>0 - 10</u>	<u>20 - 30</u>	<u>40 - 50</u>	<u>60 - 70</u>	<u>80 - 90</u>
1	0.10	0.16	0.15	0.15	0.14
2	0.13	0.08	0.15	0.16	0.14
3	0.11	0.10	0.10	0.09	0.12
4	0.10	0.12	0.11	0.13	0.13
5	0.15	0.13	0.13	0.13	0.11
6	0.14	0.11	0.13	0.15	0.15
7	0.24	0.14	0.14	0.13	0.15
8	0.13	0.13	0.15	0.15	0.11
9	0.18	0.16	0.15	0.31	0.32
10	0.22	0.13	0.13	0.13	0.13
11	0.13	0.19	0.12	0.13	0.13
12	0.13	0.13	0.15	0.13	0.15
13	0.15	0.15	0.15	0.15	0.13
14	0.13	0.16	0.15	0.13	0.13
15	0.15	0.16	0.19	0.15	0.15
16	0.16	0.16	0.13	0.15	0.18
17	0.13	0.13	0.13	0.15	0.13
18	0.12	0.15	0.15	0.16	0.15
19	0.13	0.19	0.21	0.27	NA
20	0.16	0.13	0.10	0.12	0.15

Appendix 40
(Cont'd)

Stand Number	Depth in centimeters				
	0 - 10	20 - 30	40 - 50	60 - 70	80 - 90
21	0.12	0.12	0.12	0.12	0.15
22	0.15	0.15	0.13	NA	NA
23	0.15	0.15	NA	NA	NA
24	0.13	0.12	0.15	0.19	NA
25	0.13	0.13	0.12	0.12	NA
26	0.16	0.15	0.15	NA	NA
27	0.13	0.13	NA	NA	NA
28	0.19	0.13	0.13	NA	NA
29	0.16	NA	NA	NA	NA
30	0.28	0.24	NA	NA	NA
32	0.18	0.19	0.19	0.18	0.22
33	0.15	0.18	0.16	0.16	0.15
34	0.13	0.19	0.18	0.19	0.18
35	0.16	0.12	0.13	0.15	0.15
36	0.15	0.13	0.15	0.13	0.16
37	0.16	0.21	0.18	0.31	0.35
38	0.29	0.24	0.14	0.12	0.15
39	0.12	0.13	0.16	0.18	0.19
40	0.13	0.16	0.15	0.16	0.16
41	0.13	0.12	0.15	0.16	0.15

Appendix 40
(Cont'd)

Stand Number	Depth in Centimeters				
	0 -- 10	20 -- 30	40 -- 50	60 -- 70	80 -- 90
42	0.15	0.18	0.22	0.21	0.19
43	0.13	0.13	0.16	0.18	0.16
44	0.16	0.18	0.16	0.47	0.16
45	0.16	0.16	0.29	0.35	0.27
46	0.27	0.29	0.33	0.33	0.29
47	0.29	0.31	0.29	0.31	0.40
48	0.27	0.31	0.29	0.31	0.31
49	0.24	0.24	0.18	0.22	0.21
50	0.22	0.24	0.27	NA	NA
51	0.22	0.29	0.33	0.37	0.47
52	0.22	0.27	0.27	0.24	NA
53	0.29	0.27	0.24	0.24	0.22
54	0.27	0.22	0.20	NA	NA
55	0.27	0.27	0.24	0.24	NA
56	0.29	0.20	0.18	0.20	NA
57	0.22	NA	NA	NA	NA
58	0.22	0.20	0.29	NA	NA
59	0.21	NA	NA	NA	NA
60	0.24	0.20	NA	NA	NA
61	0.31	0.31	0.24	NA	NA

Appendix 41

Magnesium Contents of the Soil Samples at Various Depths
in meq/100gm

Stand Number	Depth in Centimeters				
	0 - 10	20 - 30	40 - 50	60 - 70	80 - 90
1	2.52	3.52	3.20	4.48	3.04
2	3.04	2.56	2.56	3.68	3.52
3	2.40	3.20	2.40	2.88	4.16
4	2.56	2.24	2.40	3.68	3.84
5	4.00	4.48	4.64	4.48	4.00
6	4.80	4.32	3.84	3.52	3.84
7	3.36	2.72	2.24	2.24	2.88
8	4.48	2.56	2.24	1.60	0.32
9	4.00	2.24	3.52	2.88	2.56
10	3.64	6.72	3.84	3.20	2.56
11	2.56	4.00	5.44	6.72	5.28
12	2.56	2.24	3.60	4.08	2.80
13	2.24	0.96	0.32	1.92	2.88
14	6.24	1.28	0.80	1.28	2.88
15	4.16	1.28	1.28	1.92	1.92
16	3.20	1.76	2.08	1.28	2.56
17	2.88	1.92	1.76	2.52	2.36
18	3.68	2.88	2.56	1.76	1.60
19	4.80	2.56	2.24	2.08	NA
20	2.24	2.24	1.44	1.92	2.24

Appendix 41
(Cont'd)

Stand Number	Depth in Centimeters				
	0 -- 10	20 -- 30	40 -- 50	60 -- 70	80 -- 90
21	2.24	1.28	1.76	1.44	1.60
22	3.20	1.76	2.08	NA	NA
23	1.92	1.60	NA	NA	NA
24	1.60	1.12	0.80	1.12	NA
25	2.08	1.28	1.12	0.64	NA
26	3.20	1.28	0.96	NA	NA
27	2.40	1.12	NA	NA	NA
28	1.60	1.12	0.64	NA	NA
29	3.20	NA	NA	NA	NA
30	4.80	2.88	NA	NA	NA
32	1.76	2.24	3.52	4.16	2.64
33	3.20	3.04	5.28	3.52	4.32
34	4.80	4.32	3.84	3.84	3.84
35	6.40	4.96	5.28	5.12	4.64
36	4.00	3.04	3.20	4.48	4.80
37	4.48	3.36	2.40	2.56	2.88
38	3.68	1.05	4.48	3.52	4.16
39	5.92	3.20	2.40	4.64	2.56
40	4.00	2.88	2.40	2.56	2.56
41	4.00	2.72	2.88	2.40	2.56

Appendix 41
(Cont'd)

Stand Number	Depth in Centimeters				
	0 -- 10	20 -- 30	40 -- 50	60 -- 70	80 -- 90
42	5.12	2.24	1.60	1.76	2.56
43	3.84	2.72	1.92	1.92	2.56
44	5.12	3.52	2.08	2.08	3.20
45	3.36	1.60	1.92	1.60	2.40
46	4.48	2.56	2.08	2.24	1.92
47	3.20	1.44	1.44	0.96	1.60
48	4.48	1.60	1.92	1.60	3.20
49	7.04	3.68	2.24	2.24	1.92
50	1.44	2.40	1.92	NA	NA
51	2.56	2.72	5.44	4.96	2.24
52	1.92	1.28	1.60	2.24	NA
53	2.40	3.84	1.60	1.60	1.60
54	1.60	1.92	1.60	NA	NA
55	1.60	1.60	1.28	1.44	NA
56	1.60	0.96	1.28	1.12	NA
57	2.56	NA	NA	NA	NA
58	2.56	1.28	0.96	NA	NA
59	1.76	NA	NA	NA	NA
60	2.24	0.96	NA	NA	NA
61	1.76	2.24	1.60	NA	NA

Appendix 42

Potassium Contents of the Soil Samples at Various Depths

in meq/100gm

<u>Stand</u> <u>Number</u>	<u>Depth in Centimeters</u>				
	<u>0 -- 10</u>	<u>20 -- 30</u>	<u>40 -- 50</u>	<u>60 -- 70</u>	<u>80 -- 90</u>
1	0.71	0.34	0.40	0.44	0.34
2	0.66	0.33	0.39	0.40	0.33
3	1.19	1.02	0.74	0.50	0.85
4	0.89	1.19	0.64	0.65	0.87
5	1.79	1.67	1.65	1.49	0.85
6	0.87	0.77	0.54	0.34	0.25
7	0.36	0.26	0.34	0.23	0.25
8	0.33	0.29	0.19	0.19	0.13
9	0.57	0.41	0.48	0.30	0.30
10	1.22	1.72	1.57	1.12	0.58
11	3.24	2.73	2.68	2.71	2.87
12	0.85	0.74	0.51	0.46	0.46
13	1.06	0.66	0.43	0.41	0.39
14	3.30	0.60	0.48	0.44	0.67
15	2.00	0.46	0.34	0.32	0.34
16	1.13	0.60	0.43	0.37	0.32
17	0.99	0.73	0.53	0.48	1.05
18	1.42	0.85	0.69	0.55	0.50
19	1.47	0.99	1.10	0.60	NA
20	0.99	0.97	0.82	0.80	0.80

Appendix 42
(Cont'd)

Stand Number	Depth in Centimeters				
	0 -- 10	20 -- 30	40 -- 50	60 -- 70	80 -- 90
21	0.99	0.78	0.57	0.46	0.53
22	1.26	0.97	0.82	NA	NA
23	0.55	0.53	NA	NA	NA
24	0.67	0.48	0.53	0.51	NA
25	0.74	0.48	0.34	0.37	NA
26	0.94	0.55	0.60	NA	NA
27	0.85	0.55	NA	NA	NA
28	0.60	0.39	0.39	NA	NA
29	0.64	NA	NA	NA NA	NA
30	0.74	0.62	NA	NA	NA
32	0.80	0.73	0.60	0.58	0.64
33	1.51	1.05	0.60	0.55	0.46
34	1.17	1.26	1.26	1.06	0.66
35	1.70	1.29	1.36	1.26	0.99
36	2.34	2.16	2.21	2.14	2.06
37	0.51	0.35	0.29	0.27	0.23
38	2.18	1.93	1.86	1.67	1.72
39	2.43	1.84	1.28	0.84	0.57
40	0.65	0.44	0.40	0.28	0.20
41	0.88	0.62	0.47	0.42	0.35

Appendix 42
(Cont'd)

<u>Stand Number</u>	<u>Depth in Centimeters</u>				
	<u>0 -- 10</u>	<u>20 -- 30</u>	<u>40 -- 50</u>	<u>60 -- 70</u>	<u>80 -- 90</u>
42	0.81	0.72	0.53	0.48	0.35
43	2.32	1.41	0.81	0.92	0.87
44	2.58	1.75	1.25	1.36	1.47
45	1.61	1.25	0.66	0.37	0.41
46	1.17	0.71	0.41	0.41	0.37
47	0.39	0.23	0.23	0.19	0.14
48	1.06	0.41	0.37	0.39	0.37
49	2.27	1.59	1.06	1.08	1.49
50	1.20	0.89	0.94	NA	NA
51	1.19	0.96	1.22	1.28	1.17
52	0.94	0.66	0.67	0.53	NA
53	0.80	0.80	0.64	0.44	0.57
54	1.06	0.96	0.80	NA	NA
55	0.82	0.62	0.44	0.41	NA
56	0.66	0.50	0.41	0.37	NA
57	0.83	NA	NA	NA	NA
58	0.62	0.44	0.23	NA	NA
59	0.48	NA	NA	NA	NA
60	0.51	0.35	NA	NA	NA
61	0.43	0.35	0.30	NA	NA

Appendix 43

Manganese Contents of the Soil Samples at Various Depths
in meq/100gm

<u>Stand</u> <u>Number</u>	<u>Depth in Centimeters</u>				
	<u>0 .. 10</u>	<u>20 .. 30</u>	<u>40 .. 50</u>	<u>60 .. 70</u>	<u>80 .. 90</u>
1	0.19	0.05	0.02	0.01	0.02
2	0.36	0.22	0.02	0.08	0.05
3	0.42	0.14	0.07	0.05	0.05
4	0.23	0.11	0.07	0.04	0.03
5	0.13	0.02	0.02	0.02	0.01
6	0.20	0.05	0.04	0.03	0.02
7	0.13	0.02	0.04	0.03	0.02
8	0.11	0.06	0.05	0.03	0.03
9	0.09	0.02	0.09	0.05	0.03
10	0.28	0.09	0.02	0.01	0.02
11	0.09	0.02	0.01	0.01	0.01
12	0.14	0.05	0.03	0.02	0.02
13	0.06	0.04	0.02	0.02	0.02
14	0.02	0.05	0.03	0.02	0.01
15	0.09	0.04	0.04	0.02	0.02
16	0.09	0.03	0.04	0.03	0.04
17	0.06	0.04	0.03	0.02	0.09
18	0.05	0.05	0.02	0.02	0.01
19	0.04	0.02	0.02	0.04	NA
20	0.03	0.03	0.01	0.01	0.01

Appendix 43
(Cont'd)

<u>Stand</u> <u>Number</u>	<u>Depth in Centimeters</u>				
	<u>0 - 10</u>	<u>20 - 30</u>	<u>40 - 50</u>	<u>60 - 70</u>	<u>80 - 90</u>
21	0.02	0.01	0.01	0.01	0.01
22	0.03	0.01	0.01	NA	NA
23	0.04	0.02	NA	NA	NA
24	0.02	0.01	0.01	0.01	NA
25	0.02	0.01	0.01	0.01	NA
26	0.04	0.01	0.01	NA	NA
27	0.03	0.01	NA	NA	NA
28	0.01	0.01	0.01	NA	NA
29	0.04	NA	NA	NA	NA
30	0.09	0.01	NA	NA	NA
32	0.30	0.12	0.05	0.05	0.05
33	0.15	0.07	0.08	0.04	0.05
34	0.04	0.02	0.05	0.03	0.01
35	0.12	0.01	0.02	0.01	0.01
36	0.07	0.01	0.01	0.01	0.02
37	0.11	0.08	0.09	0.04	0.03
38	0.07	0.01	0.02	0.04	0.02
39	0.09	0.04	0.09	0.08	0.10
40	0.09	0.07	0.08	0.06	0.04
41	0.12	0.09	0.09	0.10	0.07

Appendix 43
(Cont'd)

<u>Stand Number</u>	<u>Depth in Centimeters</u>				
	<u>0 -- 10</u>	<u>20 -- 30</u>	<u>40 -- 50</u>	<u>60 -- 70</u>	<u>80 -- 90</u>
42	0.09	0.05	0.05	0.04	0.04
43	0.11	0.04	0.03	0.04	0.02
44	0.09	0.03	0.09	0.08	0.04
45	0.07	0.03	0.02	0.02	0.02
46	0.14	0.07	0.03	0.03	0.01
47	0.11	0.05	0.05	0.13	0.02
48	0.19	0.05	0.03	0.04	0.03
49	0.13	0.03	0.02	0.02	0.04
50	0.04	0.04	0.04	NA	NA
51	0.06	0.02	0.02	0.03	0.03
52	0.02	0.02	0.02	0.01	NA
53	0.03	0.02	0.01	0.01	0.01
54	0.03	0.02	0.04	NA	NA
55	0.02	0.01	0.02	0.03	NA
56	0.04	0.01	0.01	0.01	NA
57	0.05	NA	NA	NA	NA
58	0.02	0.01	0.01	NA	NA
59	0.03	NA	NA	NA	NA
60	0.02	0.01	NA	NA	NA
61	0.03	0.03	0.01	NA	NA

Appendix 44

Soil Colour of the Soil Samples at Various Depths

<u>Stand Number</u>	<u>Depth in Centimeters</u>				
	<u>0 ... 10</u>	<u>20 ... 30</u>	<u>40 ... 50</u>	<u>60 ... 70</u>	<u>80 ... 90</u>
1	5 3/4/1	5 4/2	5 4/6	5 5/6	5 6/4
2	5 4/2	5 4/3	5 4/4	5 4/4	7.5 7/6
3	2.5 4/4	2.5 4/4	0 4/6	0 4/6	0 4/6
4	10 6/4	5 5/4	5 5/4	2.5 3/2	2.5 3/2
5	7.5 6/4	5 4/2	2.5 4/4	2.5 4/4	5 3/3
6	5 3/1	5 4/2	2.5 4/4	2.5 4/4	2.5 4/4
7	5 4/1	5 4/1	5 3/2	2.5 3/2	2.5 3/4
8	10 3/2	10 4/2	5 3/1	5 3/2	5 3/2
9	7.5 4/4	10 5/4	7.5 5/6	7.5 5/6	7.5 7/4
10	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2
11	7.5 4/2	7.5 4/2	7.5 4/4	7.5 4/4	7.5 4/6
12	7.5 6/5	5 5/3	5 5/6	5 5/6	5 6/6
13	10 3/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/4
14	10 3/2	10 4/3	10 4/3	10 4/3	7.5 4/4
15	7.5 3/0	7.5 4/4	7.5 4/4	7.5 4/4	7.5 7/6
16	7.5 3/0	7.5 5/2	7.5 5/4	7.5 5/4	7.5 6/6
17	7.5 4/0	7.5 4/2	7.5 4/2	7.5 5/4	7.5 5/4
18	7.5 3/0	7.5 3/0	7.5 3/2	7.5 3/2	7.5 4/2
19	10 3/1	10 3/1	10 3/2	7.5 4/2	NA
20	10 3/2	10 3/2	10 4/2	10 4/2	7.5 5/4

Appendix 44
(Cont'd)

Stand Number	Depth in Centimeters				
	0 -- 10	20 -- 30	40 -- 50	60 -- 70	80 -- 90
21	10 3/1	10 3/2	10 4/5	10 6/4	10 6/4
22	10 3/1	10 3/2	10 4/2	NA	NA
23	10 3/1	10 3/2	NA	NA	NA
24	10 4/1	10 5/2	10 6/5	10 6/5	NA
25	10 3/1	10 5/3	10 5/3	10 6/3	NA
26	10 4/1	10 4/1	10 4/2	NA	NA
27	10 4/2	10 6/4	NA	NA	NA
28	10 4/2	10 4/3	10 4/3	NA	NA
29	10 3/1	NA	NA	NA	NA
30	10 3/1	10 3/1	NA	NA	NA
32	5 4/2	5 5/3	5 5/6	5 5/6	5 6/6
33	5 3/2	5 3/2	5 3/3	5 3/3	2.5 3/4
34	5 3/1	5 3/2	5 3/2	2.5 3/6	2.5 3/6
35	2.5 3/2	5 5/4	5 4/6	2.5 3/4	2.5 3/4
36	5 4/2	5 4/2	5 4/3	5 4/4	5 4/4
37	5 4/2	2.5 3/4	2.5 4/4	2.5 4/4	2.5 4/4
38	5 4/1	5 4/2	5 4/3	5 5/4	5 4/4
39	5 4/1	5 4/3	5 4/3	5 4/6	5 5/6
40	5 4/1	5 4/1	5 4/2	5 4/3	5 5/4
41	5 4/1	5 4/2	5 4/3	5 5/4	5 5/4

Appendix 44
(Cont'd)

Stand Number	Depth in Centimeters				
	0 - 10	20 - 30	40 - 50	60 - 70	80 - 90
42	5 5/1	5 5/2	5 4/3	5 4/3	7.5 6/6
43	7.5 4/2	7.5 4/2	7.5 4/4	7.5 4/4	7.5 4/4
44	7.5 4/2	7.5 4/2	7.5 4/4	7.5 4/6	7.5 5/6
45	7.5 4/2	7.5 4/2	7.5 4/4	7.5 5/6	7.5 5/8
46	7.5 5/2	7.5 5/2	7.5 5/2	7.5 4/4	10 8/6
47	10 4/2	10 4/3	10 4/4	10 4/4	10 8/4
48	10 4/1	10 4/3	10 4/3	10 4/4	7.5 5/4
49	7.5 4/2	7.5 4/2	7.5 4/2	7.5 5/2	7.5 5/2
50	10 3/2	10 5/2	10 3/2	NA	NA
51	10 3/2	10 3/3	10 8/6	10 7/8	7.5 6/6
52	7.5 3/2	7.5 3/2	7.5 4/4	7.5 5/2	NA
53	10 3/2	10 3/3	10 4/3	10 5/4	10 5/4
54	10 3/2	10 3/2	10 4/3	10 5/2	NA
55	10 3/2	10 3/2	10 5/3	10 5/3	NA
56	10 4/2	10 4/2	10 5/4	10 5/4	NA
57	10 3/2	NA	NA	NA	NA
58	10 3/2	10 3/2	10 3/2	NA	NA
59	10 4/2	NA	NA	NA	NA
60	10 3/1	10 4/2	NA	NA	NA
61	10 3/2	10 5/3	10 4/3	NA	NA

Appendix 45

Altitude and Slope of the Stands in the Study Area

<u>Stand Number</u>	<u>Altitude (m)</u>	<u>Slope (°)</u>	<u>Stand Number</u>	<u>Altitude (m)</u>	<u>Slope (°)</u>
1	2500	5	21	3400	28
2	2545	5	22	3445	25
3	2590	10	23	3490	10
4	2635	7	24	3535	10
5	2680	10	25	3580	25
6	2725	12	26	3625	32
7	2770	13	27	3670	30
8	2815	15	28	3715	15
9	2860	20	29	3760	25
10	2905	5	30	2805	30
11	2950	12	32	2500	3
12	2995	11	33	2545	5
13	3040	10	34	2590	10
14	3085	8	35	2635	12
15	3130	13	36	2680	5
16	3175	14	37	2725	4
17	3220	15	38	2770	23
18	3265	17	39	2815	15
19	3310	30	40	2860	25
20	3355	5	41	2905	25

Appendix 45
(Cont'd)

Stand Number	Altitude (m)	Slope (°)	Stand Number	Altitude (m)	Slope (°)
42	2950	5	52	3400	6
43	2995	3	53	2445	15
44	3040	5	54	3490	5
45	3085	4	55	3535	20
46	3130	5	56	3580	30
47	3175	20	57	3625	20
48	3220	22	58	3670	25
49	3265	35	59	3715	35
50	3310	13	60	3760	5
51	3355	25	61	3805	15

Appendix 46

Texture of the Soil Samples at Various Depths

in Percent

Stand Number	Soil Particle	Depth in Centimeters				
		0 -- 10	20 -- 30	40 -- 50	60 -- 70	80 -- 90
1	Sand	69.70	59.68	52.68	50.68	53.68
	Clay	4.00	18.96	25.96	16.30	26.96
	Silt	26.30	21.36	21.36	33.02	19.36
2	Sand	66.68	67.96	57.52	53.96	54.96
	Clay	10.96	7.96	20.96	30.96	29.96
	Silt	22.36	34.08	21.72	15.08	15.08
3	Sand	59.96	54.68	51.68	49.68	51.04
	Clay	20.96	29.68	36.68	39.68	40.68
	Silt	19.08	15.64	11.64	10.64	8.28
4	Sand	60.68	77.68	52.68	52.32	52.68
	Clay	15.68	17.04	31.68	36.68	36.68
	Silt	23.64	5.28	15.64	11.00	10.64
5	Sand	74.68	57.68	53.68	50.68	55.32
	Clay	9.68	27.68	35.68	39.32	35.32
	Silt	15.64	14.64	10.64	10.00	9.36
6	Sand	78.96	70.32	54.32	53.24	51.24
	Clay	10.32	16.68	29.68	32.68	34.68
	Silt	10.72	13.00	16.00	14.08	14.08
7	Sand	77.04	64.96	54.96	51.96	49.96
	Clay	6.68	20.68	28.68	34.68	38.04
	Silt	16.28	14.36	16.36	13.36	12.00
8	Sand	77.98	68.32	59.32	57.32	55.32
	Clay	6.04	17.04	24.40	25.04	26.04
	Silt	15.98	14.64	16.28	17.64	18.64
9	Sand	66.32	54.32	62.32	56.32	55.32
	Clay	18.04	27.68	23.04	30.68	29.68
	Silt	15.64	18.00	14.64	13.00	15.00
10	Sand	81.32	70.32	59.32	49.32	50.32
	Clay	4.68	8.32	20.32	29.32	33.32
	Silt	14.00	21.68	20.36	21.38	16.38

Appendix 46
(Cont'd)

Stand Number	Soil Particle	Depth in Centimeters				
		0 - 10	20 - 30	40 - 50	60 - 70	80 - 90
11	Sand	71.32	58.32	52.32	55.68	52.32
	Clay	6.32	10.66	25.32	22.52	31.52
	Silt	20.36	31.02	22.36	22.00	16.36
12	Sand	65.68	60.68	58.88	54.88	53.88
	Clay	2.32	5.40	20.40	23.40	28.04
	Silt	32.00	33.92	20.72	21.72	18.08
13	Sand	79.88	74.88	61.88	53.88	48.88
	Clay	3.40	3.40	16.40	24.40	31.40
	Silt	16.72	21.72	21.72	21.72	19.72
14	Sand	73.88	69.96	71.60	59.88	51.60
	Clay	7.40	8.40	5.40	21.40	29.04
	Silt	18.72	21.64	23.00	18.72	19.36
15	Sand	79.24	66.60	61.60	52.60	52.60
	Clay	2.04	12.40	16.40	28.04	29.68
	Silt	18.72	21.00	22.00	19.36	17.72
16	Sand	73.24	66.24	55.88	59.24	57.24
	Clay	5.04	11.04	21.04	20.04	26.04
	Silt	21.72	22.72	23.08	20.72	16.72
17	Sand	78.60	86.96	65.32	51.32	75.32
	Clay	1.40	13.40	11.04	25.68	3.68
	Silt	20.00	9.64	23.64	23.00	21.00
18	Sand	79.32	76.32	67.52	65.32	56.96
	Clay	3.68	3.68	10.68	10.68	17.68
	Silt	17.00	20.00	22.00	24.00	25.36
19	Sand	80.32	81.52	79.60	70.32	NA
	Clay	2.68	3.04	3.68	10.68	NA
	Silt	17.00	15.64	16.72	19.00	NA
20	Sand	76.32	76.32	74.68	61.32	56.32
	Clay	2.68	2.68	5.32	17.68	21.32
	Silt	21.00	21.00	20.00	21.00	22.36

Appendix 46
(Cont'd)

Stand Number	Soil Particle	Depth in Centimeters				
		0 - 10	20 - 30	40 - 50	60 - 70	80 - 90
21	Sand	77.32	68.32	52.32	48.68	64.32
	Clay	3.68	9.68	21.68	22.68	12.68
	Silt	19.00	22.00	26.00	28.64	23.00
22	Sand	75.96	71.96	63.96	NA	NA
	Clay	3.04	10.68	14.04	NA	NA
	Silt	21.00	17.36	22.00	NA	NA
23	Sand	73.96	77.96	NA	NA	NA
	Clay	4.04	5.04	NA	NA	NA
	Silt	22.00	17.00	NA	NA	NA
24	Sand	75.32	74.96	60.96	60.96	NA
	Clay	6.04	10.04	20.04	18.68	NA
	Silt	18.64	15.00	19.00	20.36	NA
25	Sand	73.96	71.96	74.96	75.60	NA
	Clay	4.04	10.68	8.68	7.40	NA
	Silt	22.00	17.36	16.36	17.00	NA
26	Sand	74.60	78.60	77.60	NA	NA
	Clay	2.40	1.40	3.40	NA	NA
	Silt	23.00	20.00	19.00	NA	NA
27	Sand	77.60	61.60	NA	NA	NA
	Clay	3.40	21.60	NA	NA	NA
	Silt	19.00	16.80	NA	NA	NA
28	Sand	78.60	76.80	78.60	NA	NA
	Clay	2.40	3.40	5.40	NA	NA
	Silt	19.00	14.80	16.00	NA	NA
29	Sand	73.60	NA	NA	NA	NA
	Clay	3.40	NA	NA	NA	NA
	Silt	23.00	NA	NA	NA	NA
30	Sand	75.60	75.60	NA	NA	NA
	Clay	2.40	3.40	NA	NA	NA
	Silt	22.00	21.00	NA	NA	NA

Appendix 46
(Cont'd)

Stand Number	Soil Particle	Depth in Centimeters				
		0 -- 10	20 -- 30	40 -- 50	60 -- 70	80 -- 90
32	Sand	67.68	61.68	51.68	53.04	55.68
	Clay	10.68	18.32	33.32	33.32	33.32
	Silt	21.64	20.00	15.00	13.64	11.00
33	Sand	65.68	65.68	56.68	57.68	51.68
	Clay	15.32	16.32	28.32	28.32	38.32
	Silt	19.00	18.00	15.00	14.00	10.00
34	Sand	69.68	64.68	58.68	50.68	52.68
	Clay	13.32	17.32	24.32	38.52	37.32
	Silt	17.00	18.00	17.00	11.00	10.00
35	Sand	68.68	61.68	47.68	52.68	48.68
	Clay	13.32	22.32	40.32	37.32	42.32
	Silt	18.00	16.00	12.00	10.00	9.00
36	Sand	64.68	61.68	54.68	51.32	50.32
	Clay	10.32	17.32	24.32	35.04	37.68
	Silt	25.00	21.00	21.00	13.64	12.00
37	Sand	69.32	52.68	48.68	50.68	48.68
	Clay	12.32	32.68	39.68	38.32	40.32
	Silt	18.36	14.64	11.64	11.00	11.00
38	Sand	66.68	62.68	53.68	53.32	54.32
	Clay	8.32	17.32	26.32	35.04	35.04
	Silt	25.00	20.00	20.00	11.64	10.64
39	Sand	71.68	57.68	53.68	48.68	49.68
	Clay	8.32	22.32	29.32	35.32	37.32
	Silt	20.00	20.00	17.00	16.00	13.00
40	Sand	74.68	62.68	58.68	51.68	51.68
	Clay	11.32	16.32	23.32	34.32	36.32
	Silt	14.00	21.00	18.00	14.00	12.00
41	Sand	70.68	62.68	57.68	55.68	51.68
	Clay	10.32	15.32	26.32	26.32	30.32
	Silt	19.00	22.00	16.00	18.00	18.00

Appendix 46
(Cont'd)

Stand Number	Soil Particle	Depth in Centimeters				
		0 - 10	20 - 30	40 - 50	60 - 70	80 - 90
42	Sand	71.68	64.68	57.68	53.32	52.32
	Clay	4.32	10.32	8.16	25.68	32.68
	Silt	24.00	25.00	34.16	21.00	15.00
43	Sand	67.68	65.68	62.68	54.32	51.32
	Clay	6.32	11.32	12.32	25.68	31.68
	Silt	26.00	23.00	21.00	20.00	17.00
44	Sand	72.32	66.32	57.32	54.32	51.26
	Clay	3.68	9.68	19.32	24.68	32.68
	Silt	24.00	24.00	23.36	21.00	16.00
45	Sand	76.68	68.32	57.32	56.32	52.32
	Clay	3.32	6.32	18.32	25.68	31.68
	Silt	20.00	25.30	24.30	18.00	16.00
46	Sand	66.68	69.68	62.68	60.16	60.16
	Clay	5.32	9.32	13.32	24.68	29.68
	Silt	28.00	21.00	24.00	15.16	10.16
47	Sand	75.32	69.68	60.68	55.96	52.32
	Clay	3.32	9.32	17.32	22.68	19.68
	Silt	21.36	21.00	22.00	21.36	28.00
48	Sand	76.68	71.68	70.68	65.32	45.32
	Clay	2.32	5.32	4.32	8.68	19.68
	Silt	21.00	23.00	25.00	26.00	37.00
49	Sand	74.68	72.68	66.68	53.68	54.68
	Clay	2.32	3.32	8.32	22.32	27.32
	Silt	23.00	24.00	25.00	24.00	18.00
50	Sand	75.68	76.68	72.68	NA	NA
	Clay	2.32	3.32	3.32	NA	NA
	Silt	22.00	20.00	24.00	NA	NA
51	Sand	74.68	73.68	50.68	49.68	50.68
	Clay	2.32	3.32	15.32	16.32	12.32
	Silt	23.00	23.00	34.00	34.00	37.00

Appendix 46
(Cont'd)

Stand Number	Soil Particle	Depth in Centimeters				
		0 -- 10	20 -- 30	40 -- 50	60 -- 70	80 -- 90
52	Sand	77.68	74.68	70.68	54.68	NA
	Clay	1.32	5.32	8.32	23.32	NA
	Silt	21.00	20.00	21.00	22.00	NA
53	Sand	77.68	77.68	69.68	57.68	60.68
	Clay	2.32	2.32	7.32	21.32	19.32
	Silt	20.00	20.00	23.00	21.00	20.00
54	Sand	72.68	75.68	68.68	NA	NA
	Clay	4.32	2.32	10.32	NA	NA
	Silt	23.00	22.00	21.00	NA	NA
55	Sand	77.68	74.68	74.32	58.32	NA
	Clay	1.32	4.32	8.68	21.68	NA
	Silt	21.00	21.00	17.00	20.00	NA
56	Sand	69.32	77.68	76.68	76.32	NA
	Clay	4.68	3.68	8.68	9.32	NA
	Silt	26.00	18.64	14.64	14.36	NA
57	Sand	74.32	NA	NA	NA	NA
	Clay	4.68	NA	NA	NA	NA
	Silt	21.00	NA	NA	NA	NA
58	Sand	76.32	77.32	78.68	NA	NA
	Clay	3.68	5.68	8.68	NA	NA
	Silt	20.00	17.00	12.64	NA	NA
59	Sand	77.68	NA	NA	NA	NA
	Clay	2.68	NA	NA	NA	NA
	Silt	19.64	NA	NA	NA	NA
60	Sand	72.32	70.32	NA	NA	NA
	Clay	3.32	3.68	NA	NA	NA
	Silt	24.36	26.00	NA	NA	NA
61	Sand	72.32	80.32	72.32	NA	NA
	Clay	3.68	6.68	10.68	NA	NA
	Silt	24.00	13.00	17.00	NA	NA

DECLARATION

I, the undersigned, declare that this thesis is my work and that all sources of material used for the thesis have been duly acknowledged.

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Date of submission - July, 1984.