A STUDY ON THE STRUCTURE OF A MONTANE FOREST - THE MENAGESHA STATE FOREST

A dissertation submitted to
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the Requirements for the
Degree of Master of Science in Biology

by
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To

The late major Nigussie Tuji, my brother who encouraged me to continue my higher education.

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A B S T R A C T

A STUDY ON THE STRUCTURE OF A MONTANE FOREST

THE MENAGESHA STATE FOREST

BY

SEBSEBE DEMISSEW

In order to have a better management for existing forests, and to reafforest devegetated areas an ecological study of forests is indispensable. Menagesha State Forest which is one of the few remaining forests in Central Ethiopia was chosen for such a study.

In the Menagesha State Forest, 50 stands were chosen by systematic sampling. All the plants found in each stand were recorded and in all 60 species of plants were identified. Soil samples from the surface, 10, 20, 30, 40, 50, and 60 cm. depths were taken and analysed in the laboratory for conductivity, pH, cations (calcium, magnesium, potassium and sodium). Measurements of slope, aspect and altitude were taken in the field. The 50 stands were classified using the Association Analysis technique in the University of Manchester Regional Computer Centre, resulting in 16 groups of stands (A, B, C, D, E, F, G, H, I, J, K, L, M, N, O and P). Each group of stands was compared with all other groups of stands to see whether there are statistically significant variations in their environmental factors (conductivity, pH, cations, slope and altitude) between them using the t-test. The results of the t-test showed that there are two more or less distinct categories of vegetation. The first category identified by + *Erica arborea* include group of stands that have a poor nutrient status, a deeper soil, and a flatter habitat than the group of stands in the - *Erica* category. The - *Erica* group of stands have soils that are relatively nutrient rich and have shallower depths. This group of

stands also occupy steeper slopes than + *Erica* category. Based on the findings of the study it is suggested that the conservation of the forest has to continue; the nutrient poor + *Erica* areas could have improved nutrient stands if shrubs including Kolfa (Mukeguracha) followed by *Maesa lanceolata* and/or *Carissa edulis* that tend to increase soil nutrients are planted, and planting conifers which increase rates of nutrient loss is avoided.

CHAPTER 1

INTRODUCTION

1.1. Aims of the Study

Historically most of the Ethiopian mountains were covered by natural forests. In recent years with the unwise use of these resources for different purposes most of the mountains are bare. Russ (1944) in his report on the status of Ethiopian forests pointed out that the Ethiopian forest resources were the greatest in East Africa and that they contained the largest coniferous trees in the continent. Mooney (1959) estimated the area under forest oover to constitute 9% of the Ethiopian land mass. Hedberg (1979) compared the 16% of the forest cover in 1954 and the 4% in 1975 and commented on the situation as follows. 'Lumbering, felling for fuel, and replacement of forest by agricultural land are continuously reducing the sparse remaining forest resources, and unless this trend is reversed there is little hope that any forest worth mentioning will remain after another ten years.'

The Menagesha State Forest is one of the few protected natural forests in the country. For wise use of this natural forest, an ecological study is necessary. This study aims at explaining the structure of the vegetation of the state forest using techniques that will enable the classification of the vegetation into groups based on homogeneity for comparison. The group are then correlated with the environmental factors, hopefully giving information that will suggest solutions to some management problems of that particular forest. Such techniques have been used by Goodal (1953), Williams & Lambert (1959, 1960), Webb et al (1967, Kershaw (1967), Poore (1968), Beals (1969), Lundgren (1969) and Tewolde (1975).

1.2. Description of the study area

1.2.1. Location

Menagesha State Forest is located about 30 Kms south-west of Addis Abeba from 38°32' to 38°34' E and from 8°56' to 9°00' N in Shoa Administrative region in central Ethiopia. (see Fig. 1 and Fig. 2).

1.2.2. Geology

It is part of the fairly well preserved volcanic dome of Wachacha. The dome covers an area of approximately 100 sq. km. and culminates in a broad, flat northern summit (c. 3350 m.) and sharp southern peak (c. 3300m.)

The geology of Wachacha has been reported by Miller et al (1966). Wachacha is an extinct volcano situated in a very complex tectonic setting, where the western margin of the main Ethiopian rift is barely defined topographically. NE - SW faulting dominates the region, but without showing on the surface contrasting with the marked escarpments further north east. The Rock types vary from a white, coarsely porphyritic sandidine trachyte forming the Wachacha summit to an extensive series of pale to dark green or grey trachytes often porphyritic with feldspar phenocrysts at the lower altitudes, white, fine grained trachyte and trachytic tuffs of intermediate hardness at the summit depression and pale-yellow, coarsely porphyritic trachytes which are well developed (hard) on the southern slopes of the volcano.

The Wachacha lavas have yielded an average age of 4.5 (s) ± 0.1 m.y. which places the last phase of volcanic activity in the Upper pliocene.

1.2.3. Climate

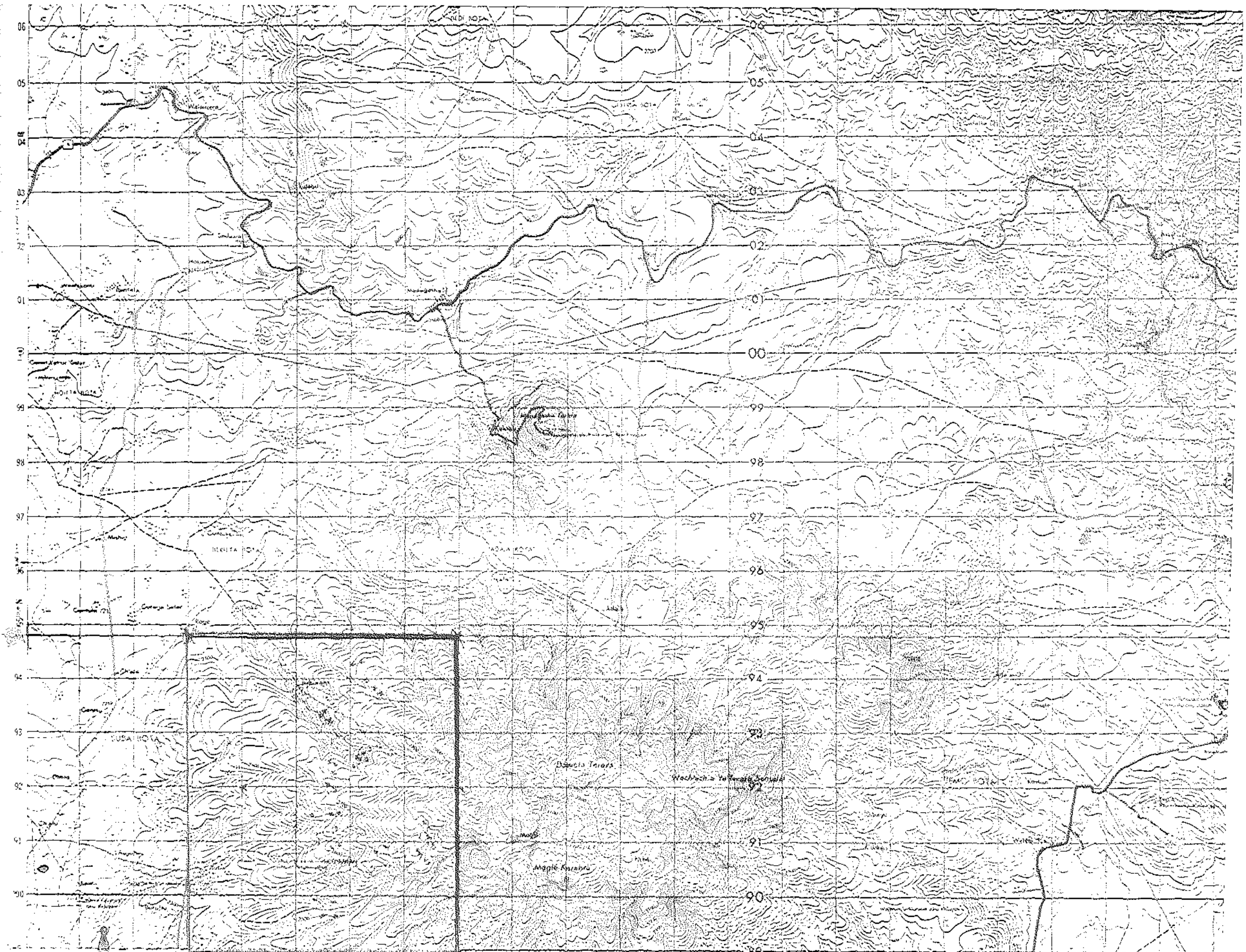
According to Daniel Gamachu (1977), the highlands of western and central Shoa are characterized by having seven rainy months from March to September. The small rains occur from March to May and the big rains in the region are from June to September. High concentration of rainfall occurs in July and very high concentration in August. Rainfall data for the forest area are not available but Addis Ababa with an altitude of 2408 m. a.s.l. which is located at 9.02°N and found only 30 kms away from the forest, receives an annual rainfall of 1270.9 mm. The Menagesha State Forest (Wachacha) with an altitude of 3300 mts a.s.l. at the northern summit is expected to receive a higher amount of rainfall.

1.2.4. Temperature

Addis Abeba with an altitude of 2408 a.s.l. has an average annual temperature of 16.3°C. By employing a temperature decrease of 1°C for 180 m. increase in altitude (Fantoli, 1965), the mean annual temperature of the area under observation would be 16.0°C in the lower parts (2440 m. a.s.l.) to 14.0°C in the higher parts (2890 m. a.s.l.)

1.2.5. Vegetation

Russ (1944) grouped the Menagesha State Forest in the coniferous and mixed forests which



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PROJECT AREA

MENAGESHA STATE FOREST (SUBA)

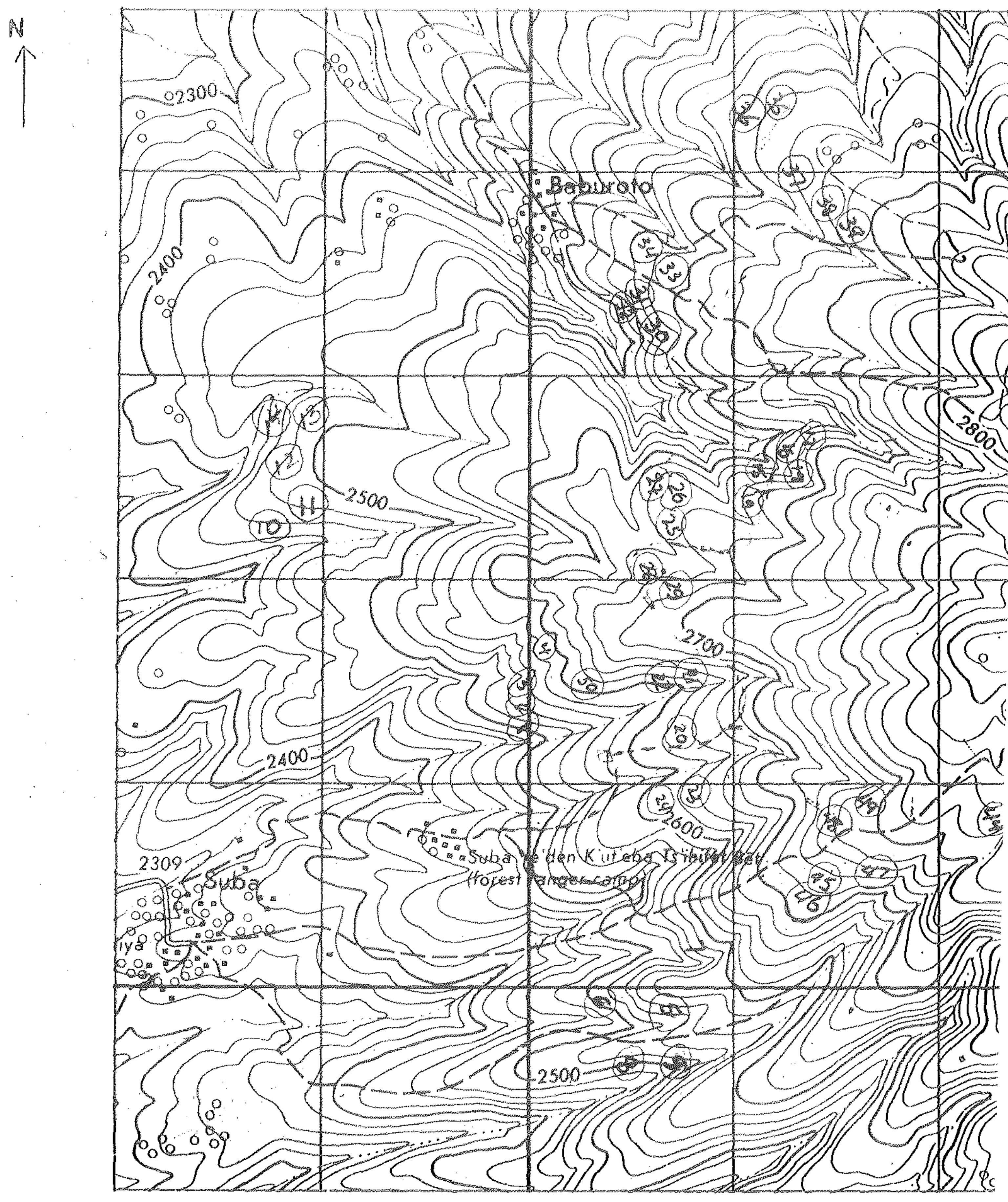


Fig-are usually mountain or slops forests. These forests according to him have certain traits of composition in common. Podocarpus gracilior is the dominant conifer at low elevations and in sheltered valleys, while Juniperus procera is found on ridges and at higher elevations. Associated with these conifers there are some hardwood species. There are more tree species associated with P. gracilior than with J. procera. These include Eckebergia capensis, Celtis kraussiana, Aningeria adolfi-friedericii, Pygeum africanum, Allophylus spp, Apodytes dimidiata, and Olea hochstetteri. Those species that associate with J. procera include Hagenia abyssinica, Olea africana, Rhus glutinosa, Ilex mitis, Allophylus spp, Bersama abyssinica, and Schefflera spp. Logan (1946) considers the forest as tropical high montane conifer forest characterized by a mixture of conifer and hardwood emergents up to 120 ft. high, the conifers being dominant particularly J. procera. Associated with J. procera, species including Pygeum africanum, Eckebergia capensis, Bersama abyssinica, Croton macrostachys, and Euphorbia spp. were found. The distinctive feature of the Juniperus association is the comparatively high incidence of Olea spp. On the higher and colder part of the forest Hagenia abyssinica is common. The shrub layer includes Sideroxylon oxycantha, Carissa edulis, Calpurnia aurea, Rosa abyssinica, Vernonia abyssinica and Teclea nobilis. The upper limit merges into a bamboo forest or mountain grassland and at its lower (warmer) limits merges with the upper montane forest which is found in the moist and warm regions and characterised by Podocarpus association.

CHAPTER 2

Collection of Field Data and Laboratory Studies

2.1. Field Data

2.1.1. Vegetation

A sample consists of a small collection from some larger aggregate about which we wish information. But no sample contains information about the whols population. This will raise the question of sampling method. An investigator has to design and conduct the sampling procedure so that the sample shall be representative of the population, then having studied the sample, he has to make correct inferences about the population (Snedecor et al 1967 pp 4 - 5). Greig-Smith (1964 pp 20-21) explains the sampling in vegetation as follows. The value of data on the composition of vegetation depends on the sampling procedure used to obtain it. With few exceptions the object in making quantiative estimates of vegetation will fall into one or other of three categories.

a. An estimate of the over all composition of the vegetation within certain boundaries, with a view to comparision with other areas or with the same area at another time.

b. The investigation of variation within the area.

c. Correlation of vegetation differences with differences in one or more habitat factors.

This division 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 the examination of variation within the area. Sometimes a compromise is possible whereby more than one objective may be attained, although perhaps at a lower level of precision, by a suitable sampling procedure. There must inevitably be an element of subjectivity in sampling because the boundaries within which a set of samples is taken are fixed by the ecologist on the basis of his judgement of what can suitably be described as one unit for the purpose in hand. 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 (Greig-Smith, 1964 pp 20-21). So, one has to choose between systematic and random sampling. The advantages of systematic sampling over random sampling are that it distributes the sample more evenly over the population and that it is easier to lay out in the field. There are two potential disadvantages (Snedecor et al 1967).

a. If the population contains a periodic type of variation, and if the interval between successive units in the systematic sample happens to coincide with the wavelength (or a multiple of it) we may obtain a sample that is highly biased.

b. There is no reliable method of estimating the standard error of the sample mean.

Some authors try to minimize the differences between the two types. According to the U.S. Bureau of the Census (1968), Generally methods of random sampling and systematic sampling will give results that do not differ very much, though systematic sampling will often have a somewhat sampling error, since it will make certain.

that the samples will be spread throughout the population. William (1973) objects to the use of random sampling in cases where the study of plants in relation to their environment is needed. In these studies quantifications of joint occurences of plants and environmental factors is needed. Though random sampling can be used to obtain these joint records, it does this much less efficiently than systematic sampling. The merit of random sampling, which is that it enables an overall comparision of the sample means and standard errors with the overall population mean and standard deviation is not essential for the above comparative purpose and random sampling is thus, besides being more laborious, less efficient and reliable.

The true characteristics of a plant community only appear when a certain minimum area is examined. Generally, it is evident that the larger the sample examined the greater will be the information obtained, whether about the species present, their quantitative representation or their patterns. Likewise a law of diminishing returns will apply in that, successive equal increases in size of sample will give successively smaller amount of additional information. The value of determining, other than empirically, any precise minimum area to be used in describing vegetation depends on whether or not there is, at some point, a sudden decrease in the amount of additional information obtained. (Greig-Smith, 1964 pp 153-154). Eventhough the concept of minimum area seems very attractive, it is not clearly defined and is of little practical use.

Clapham (1932) showed for one particular case that the variance between rectangular strips was markedly less than between squares. He also pointed out the greater ease in the field of working with strips than with squares, in avoiding trampling on part of the sample area while dividing it up for counting and examining its parts. Too great an elongation of the strip, however, carries with it the problem of exaggerated edgeeffect similar to those found with the use of very small square quadrats. The smaller the quadrat the greater the length of quadrat boundary per unit area and consequently the chance of significant edge effects due to the observer consistently including individuals that ought to be excluded or viceversa. For this reason alone, particularly if individuals of the species under consideration have a large area or ill-defined boundary at ground level, it is advisable that the quadrat not be too small.. (Greig-Smith 1964 p. 29), Tewolde(1975), and Lundgren (1969) have used 20 x 20 m. stands in Ethiopian forests and found good results. So, a quadrat size of 20 x 20 m. was adopted. The plants found in the stands were recorded as present. The trees and shrubs were counted. Unless identified without doubt in the field each plant species was numbered and pressed for identification in the laboratory.

2.1.2. Environmental Data

Hopkins (1965 p. 1 - 2) defines the environment in which a plant community exists as 'the sum total of the conditions of the environment (ecological factors) which are effective in determining the existence of a community in that place.' The environment therefore can be viewed as the sum of the complex physical and biological conditions in which the community exists. These conditions include biotic, climatic, edaphic, historical and physiogeographic factors. These factors do not affect the plants independently but interacting constantly.

For a laboratory determination of some edaphic factors, soil samples which were taken using an auger were collected from the surface, and from 10, 20, 30, 40, 50 and 60 cm. depths, except when badrock was reached, and were brought to the laboratory in polyethene bags and allowed to airdry; slope and aspect were determined using a Brunton Compass and altitude was measured using an Everest altimeter of Thommen, Switzerland.

2.2. Laboratory studies

2.2.1. Vegetation

The pressed plant specimens were identified by comparing them with the already identified plant species in the National Herbarium of the Addis Ababa University in the Science Faculty and with different descriptions of various works on the flora of Ethiopia and neighbouring countries. This include Andrew (1956), Agnew (1974), Cuffodontis (1966), Graham (1960), Milne-Redhead(1953, 1958), Mooney (1963), Tennant (1968), Thiselton-Dyer (1904), Turrill et al (1952), Verdcourt (1968, 1976). One species whose vernacular name is Kolfa Mukeguracha (Oromo language) could not be identified because it was sterile during collection. The Results are given in Table 1. In the table, all plants have field numbers. A plant with specimen number(s) means that the plant specimen(s) in kept in the National Herbarium. A plant name is followed by a string of stand number(s) in which the plant was present. Each stand number may or may not be followed by a pair of numbers. If it is followed by a pair of numbers in brackets it means that the plant is countable and the first number indicates the number of individuals taller than 50 cm., and the second those smaller than 50 cm. If the stand number is not followed by a pair of numbers, it means that the plant was a berb. The data from successive stands are separated by commas.

2.2.2. Soil analysis methods

Soil analysis methods followed were those of Jackson (1958) and Marrs et al (1978). The dried soil specimens were lightly ground with morter and pestle, and sieved through a 2 mm. sieve to remove pebbles, coarse sands and large parts of the plant material. Then the following analyses were done.

For pH measurement, a soil water mixture in the ratio of 1:2. 5, i.e. 10 gm. of soil mixed with 25 ml. of distilled water, was used and the contents were stirred for 20-30 minutes. The pH was measured using a Backman Chem Mate pH meter. For conductivity, a saturation extract prepared from a saturated paste was used and measurements were done using a type MCI (mark IV) conductivity measuring bridge. Results of pH and conductivity are given in Table 2.

Analysis for exchangeable cations, calcium, magnesium, potassium and sodium was carried out on a ammonium acetate extract. To a 50 gm. air dry sample a 100 ml. of 1M ammonium acetate colution adjusted to pH 7 was added. Theflask was shaken for several minutes and allowed to stay overnight. The contents of the flask were then filtered and the remains leached with an additional 400 ml. of ammonium acetate solution a little at a time. From the extract, potassium and sodium were determined using Pye Unicam Sp 191 atomic absorption spectrophotometer. Results are given in Table 3.

TABLE 1

Vegetation Data

Field No.	Speci- men No.	Scientific/Local Name	Stand Num
1	346	Adiantum thalictroides Schlechtend.	2, 3, 4, 8, 9, 19, 24, 37, 38, 39, 45, 47
2	343	Agauria salicifolia (Com. ex Lam.) Hook.	40(1/0), 41(3/0)
3	326	Allophylus abyssinicus (Hochst.) Radlk.	1(1/0), 3(0/1), 5(0/1) 19(2/0), 21(3/1), 22(3 31(1/0), 37(0/2), 45(5 47(1/2), 49(1/3)
4	347a	Asplenium monanthes L.	2, 6, 8, 9, 15, 20, 36
5	313	Barleria ventricosa Nees.	8
6	321	Bersama abyssinica Fresen.	1(0/2), 5(3/1), 6(0/3) 9(2/0), 13(2/5), 16(0/ 18(1/0), 19(0/2), 21(2 31(1/0), 35(3/0), 36(2 45(1/0), 46(2/0), 47(2 49(1/0), 50(0/1)
7	325	Brucea antidysenterica Mill.	18(1/0)
8	339	Calpurnea aurea (Ait.) Benth.	31(4/4)
9	-	Carissa edulis (Forssk.) Vahl.	1(2/0), 2(2/0), 3(2/2) 11(3/0), 12(3/0), 13(2 25(1/0), 26(3/5), 27(3 29(2/0), 31(3/0)

Table 1 cont'd

Field No.	Specimen No.	Scientific/Local Name	Stand Numbers
10	-	Clausena anisata (Willd.) Oliv.	9(½)
11	340	[illegible]otalaria lachnocarpa A. Rich.	33(1/0)
13	-	[illegible]scopodium pennineruum Hochst.	15(1/0), 22(0/3), 24(
14	347b	Dryopteris inaequalis (Schlechtend.) Kuntze	8, 9, 15, 20, 36, 37,
15	309	Dovyalis abyssinica (A. Rich.) Warb.	1(4/0), 2(0/1), 6(1/0 9(2/0), 15(2/0), 16(1 21(1/0), 23(2/0), 24(27(3/0), 30(3/0), 31(35(1/0), 37(1/0), 38(45(0/1), 46(1/0)
16	305,306	Dovyalis verucosa (Hochst.) Warb.	1(7/0), 2(1/0), 3(10/ 5(5/2), 6(6/0), 7(3/0 16(1/0), 20(1/0), 21(23(2/0), 24(1/0), 26(30(9/0), 31(4/0), 32(34(3/0), 35(1/0), 50(
17	-	Ekebergia capensis Sparrm.	1(1/0), 6(2/2), 8(3/0 18(2/0), 19(3/0), 21(23(4/0), 24(1/0), 30(39(1/0), 50(2/0)
18	-	Embelia schimperi Vatke	22, 37, 38, 46, 50
19	317	Erica arborea L.	10(2/0), 11(2/0), 12(25(18/6), 26(15/2), [illegible] 29(12/5), 33(5/2), 3[illegible] 41(11/0), 42(10/1), [illegible]

Table 1 cont'd

Field No.	Specimen No.	Scientific/Local Name	Stand Number
20	-	Euphorbia obovalifolia A. Rich.	1(1/0), 8(1/0)
21	322	Galiniera coffeoides Del.	13(1/0), 19(3/0), 20(24(2/0), 35(5/1), 36(
22	337	Gnidia glauca (Fresen.) Gilg.	30(2/0), 32(2/1)
23	328	Halleria lucida L.	15(1/0), 16(1/0), 17(41(3/0), 42(1/0)
24	334	Helichrysum cymosum (L.) Less sep. Fruticosum (Forssk.) Hedb.	25, 26, 27, 28, 40, 4
25	342	Hypericum lanceolatum Lam.	12(2/0), 13(2/0), 40(
26	308	Hypoestes verticillaris (Linn.f.)	1, 2, 3, 6, 7, 8, 9, 36, 38, 46
27	344	Ilex mitis (L.) Radlk.	42(1/0), 44(0/1)
28	341	Jasminum abyssinicum Hochst. ex Dc.	1, 3, 5, 6, 7, 16, 20 34, 35, 38, 39, 46, 4
29	320	Jasminum stans Pax	5(1/0), 7(2/0), 10(5/ 13(3/0), 27(2/0), 29(40(1/0), 41(1/0), 42(44(3/0), 48(3/0), 49(
30	333	Juniperus procera Hochst. ex. A. Rich.	1(3/0), 2(2/0), 3(6/0 9(1/0), 10(8/2), 11(1 13(10/0), 14(5/3), 15(17(½), 20(8/0), 21(7/ 24(3/0), 25(12/1), 26(28(12/0), 29(7/7), 30(36(0/2), 37(4/0), 38(

Table 1 cont'd

Field No.	Specimen No.	Scientific/Local Name	Stand Numbers
31	-	Koifa (Mukeguracha) local name	30(3/0), 31(2/0), 32(1/0 34(9/0)
32	329	Lobelia giberoa Hemsl.	22(4/0), 36(3/0), 46(3/4
33	-	Maesa lanceolata Forssk.	10(1/0), 12(1/0), 14(3/0 41(1/1), 49(1/0)
34	311	Maytenus sp.	1(3/0), 2(2/0), 3(2/3), 7(2/0), 11(1/0), 12(2/0), 14(2/0), 15(6/0), 16(2/0, 20(0/1), 21(1/0), 25(4/0, 27(1/8), 28(3/0), 29(5/6, 32(1/0), 33(2/0), 34(4/5, 36(1/1), 37(1/0), 38(1/0, 40(1/0), 41(1/0), 43(3/0, 47(4/0), 48(2/2), 49(2/0)
35	345	Myrica calicifolia Hochst. ex. A. Rich.	11(2/0), 13(4/0), 40(6/0) 42(0/1), 43(1/0), 44(1/0)
36	324	Myrsine africana L.	1(8/5), 3(10/2), 4(4/0), 7(10/15), 8(5/0), 9(3/0), 11(4/3), 12(1/0), 13(3/1) 16(17/0), 18(8/15), 19(1/ 21(3/0), 22(3/0), 23(1/0) 26(15/0), 27(2/2), 28(11/ 30(1/15), 31( ), 32(34( ), 35( ), 38(40( ), 41( ), 42(44( ), 45( ), 46(48( ), 49( ), 50(

Table 1 cont'd

Field No.	Specimen No.	Scientific/Local Name	Stand Number
37	338	**Nuxia** congesta R. Br. ex. Fresen.	6(3/0), 7(3/0), 33(2/0), 35(1/0), 37(1/0), 38(1/0 41(1/0), 43(4/0), 44(4/0 46(1/0), 49(2/0), 50(1/0
38	-	Olea africana Mill.	2(2/0), 3(1/0), 4(2/0), 7(4/2), 8(5/0), 9(2/0), 12(2/0), 13(2/1), 15(2/ 17(1/0), 18(4/0), 19(3/ 21(1/0), 22(4/0), 23(2/ 26(0/4), 27(3/2), 28(2/ 31(5/0), 32(2/0), 33(1/ 37(1/0), 38(1/0), 39(1/ 43(2/2), 44(0/2), 45(5/ 48(1/0), 49(5/2), 50(1/
12	319	Olinia aequipetala (Del.)Cuf.	1(2/0), 2(2/0), 3(2/0), 7(4/1), 10(4/0), 11(5/0 14(4/0), 15(3/0), 16(2/ 20(6/0), 21(4/0), 22(3/ 26(1/0), 27(2/3), 28(3/ 30(12/0), 31(3/0), 32(3 35(1/0), 36(1/1), 38(2/ 41(3/1), 42(6/0), 43(3/ 46(3/2), 47(3/0), 50(4/
39	316,332	Osyris arborea Wall. ex. Wight	10(4/0), 11(6/0), 12(6/ 25(6/0), 26(1/0), 27(2/ 41(3/0), 42(2/0), 43(3/

Table 1 cont'd

Field No.	Specimen No.	Scientific/Local Name	Stand Numbers
40	310	Otostegia minuccii Pichi-Serm.	10, 14
41	323	Pentas lanceolata (Forssk.) Deflers.	10(2/0), 19(3/0), 35(1/0), 39(1/0)
42	-	Periploca linearifolia Dill. ex. A. Rich.	8, 20, 23, 35, 50
43	315	Pittosporum sp.	11(2/0), 12(2/0), 13(0/1), 29(4/0), 31(2/0), 32(3/0), 34(3/0), 41(2/1), 42(2/0), 44(4/0), 45(1/0), 47(2/0), 48(2/0), 49(2/0)
44	-	Podocarpus gracilior Pilger.	1(0/1), 2(0/2), 5(1/4), 15 17(3/9), 18(4/1), 19(4/0), 36(2/0), 37(1/0), 50(4/5)
45	321	Pterocephalus frutescens Hochst. ex. A. Rich.	, 10
46	-	Pygeum africanum Hook.f.	1(1/0), 6(2/2), 7(4/0), 8(16(3/0), 18(½), 21(1/0), 2 24(1/0), 36(4/0), 37(3/0), 39(4/0), 46(3/0), 47(2/0)
47	336	Rapanea melanophloea (L.) Mez. Sens. lat.	18(2/3), 19(15/4), 20(10/3 22(1/0), 23(8/0), 24(6/4), 36(8/6), 37(7/3), 39(2/0), 42(5/7), 43(4/0), 44(3/0)
48	-	Rhamnus prinoides L'Herit.	6(2/0), 9(2/0)

Table 1 cont'd

Field No.	Specimen No.	Scientific/Local Name	Stand N[illegible]
49	327	Rhus glutinosa Hochst. ex. A. Rich.	11(2/3), 12(0/2), 2[illegible] 26(1/0), 27(½), 2[illegible] 31(1/0), 32(2/0), 37(3/2), 38(1/0), 46(1/0), 47(5/0),
50	318	Rhus vulgaris Meikle	7(1/0), 10(1/0), 1[illegible] 48(3/0), 50(1/0)
51	-	Rosa abyssinica R. Br.	11(1/6), 13(2/0), 25(1/0), 27(1/0), 41(1/0)
52	-	Rubus apetalus Poin.	5, 18, 19, 45, 46
53	349	Satureja biflora (Buch-Ham.ex. Don) Briq.	40, 41
54	-	Schafflera abyssinica (Hochst.ex.A.Rich)	32(1/0)
55	331	Senecio [illegible] Vatke	3(2/0), 8(3/0), 1[illegible]
56	307	Sideroxylon gillettii Hutch. & E Bruce	1(3/0), 4(2/0), 5[illegible] 10(5/0), 11(2/0), 20(1/0), 22(5/0), 28(1/0), 30(8/0), 34(2/0), 47(1/0),
57	-	Teclea nobilis Del.	2(2/0), 3(3/0), 2[illegible]
58	-	Urera hypselodendron (Hochst. ex.A.Rich) Wedd.	8, 9, 19
59	-	Vernonia amygdalina Del.	5(3/0)
60	314	Vernonia leopoldii (Sch.Bip.) Vatke	9(1/0), 10(2/0), [illegible] 37(9/0), 38(1/0), 41(2/0)

TABLE 2

Soil Data

PH at various Depths (cm)								Specific Conductivity at Various Depths (mmhos/cm)						
Stand No.	0	10	20	30	40	50	60	Stand No.	0	10	20	30	40	50	60
1	7.3	7.1	7.1	7.0	6.9	6.7	6.2	1	330	280	280	210	190	140	130
2	6.3	6.6	6.5	6.0	R	R	R	2	500	220	170	200	R	R	R
3	6.9	6.7	6.8	6.8	6.7	6.8	6.8	3	200	280	260	250	230	190	160
4	6.3	6.4	6.4	6.3	6.3	6.3	6.3	4	370	200	170	210	170	150	R
5	6.0	6.4	6.1	R	R	R	R	5	370	320	270	R	R	R	R
6	6.9	7.8	7.9	7.9	7.8	7.8	7.8	6	340	310	310	330	300	280	220
7	6.5	6.7	6.5	5.6	R	R	R	7	300	240	170	60	R	R	R
8	6.5	6.5	6.4	R	R	R	R	8	400	400	340	R	R	R	R
9	6.3	6.8	6.8	R	R	R	R	9	470	370	350	R	R	R	R
10	5.6	5.4	5.4	5.3	5.3	5.4	5.3	10	140	80	70	70	80	70	70
11	5.5	5.4	5.2	5.2	5.2	5.4	5.4	11	120	110	100	60	50	60	60
12	6.2	5.8	5.5	5.6	5.8	5.8	5.6	12	100	80	90	70	70	70	60
13	6.0	5.5	5.6	5.6	5.7	5.7	5.7	13	130	100	80	60	40	50	60
14	6.1	6.0	6.0	6.0	R	R	R	14	180	140	130	L	120	R	R
15	6.6	6.6	6.5	6.8	6.7	6.0	5.5	15	370	350	260	240	230	170	120
16	6.2	6.9	6.9	6.9	6.6	R	R	16	320	310	240	200	200	R	R
17	6.3	6.1	6.0	6.5	5.5	5.6	7.0	17	180	150	130	150	70	60	60
18	6.0	6.4	6.5	6.6	6.5	6.4	R	18	290	240	220	210	200	R	R

Table 2 contl.

Stand No.	0	10	20	30	40	50	60	Stand No.	0	10	20	30	40	50	60
19	5.5	6.2	6.6	7.0	6.9	7.0	R	19	70	240	240	230	210	230	R
20	7.1	7.0	7.1	6.8	6.6	5.5	R	20	260	260	260	210	170	100	R
21	6.7	6.8	6.9	6.7	6.7	6.5	R	21	350	290	260	220	200	140	R
22	6.3	6.5	6.6	L	6.6	6.8	6.6	22	280	280	240	L	280	210	110
23	6.0	L	6.2	6.1	6.0	6.1	6.3	23	270	L	200	110	170	100	60
24	6.2	6.1	6.0	R	R	R	R	24	390	260	230	R	R	R	R
25	7.0	5.6	5.7	5.6	5.6	R	R	25	100	60	60	50	50	R	R
26	5.5	5.3	5.3	5.3	5.4	R	R	26	110	110	120	60	50	R	R
27	5.3	5.2	5.2	R	R	R	R	27	70	50	40	R	R	R	R
28	5.5	5.6	5.2	R	R	R	R	28	40	40	30	60	R	R	R
29	5.6	5.4	5.3	5.4	5.5	R	R	29	160	50	60	70	R	R	R
30	5.7	5.7	6.8	6.1	6.4	6.5	R	30	130	130	L	150	100	100	R
31	5.8	7.2	7.3	7.3	R	R	R	31	160	210	220	290	R	R	R
32	6.5	6.5	6.9	7.1	7.2	R	R	32	150	140	170	190	190	R	R
33	6.0	5.7	5.4	5.3	5.5	5.6	R	33	120	70	50	70	30	R	R
34	6.0	5.9	5.6	5.5	5.5	R	R	34	150	120	100	80	60	R	R
35	5.7	6.0	6.3	6.3	5.7	6.4	R	35	280	310	200	200	100	200	R
36	6.6	5.9	5.9	6.2	6.3	6.1	R	36	320	150	170	190	120	180	R
37	7.0	6.9	6.8	R	R	R	R	37	400	200	230	R	R	R	R
38	6.7	6.9	7.0	7.2	R	R	R	38	310	230	240	230	R	R	R
39	6.1	6.3	6.4	6.7	6.6	6.5	R	39	190	180	160	140	140	130	R

Table 2 contd.

Stand No.	0	10	20	30	40	50	60	Stand No.	0	10	20	30	40	50	60
40	6.0	6.0	5.3	5.8	5.8	5.7	R	40	170	120	70	60	70	R	R
41	5.6	5.6	5.6	5.5	5.6	5.5	R	41	140	110	100	80	60	60	R
42	5.2	5.1	5.4	5.5	5.5	5.4	5.4	42	120	100	60	60	60	50	50
43	5.4	5.4	5.4	5.4	5.5	5.6	5.6	43	150	90	70	50	40	50	40
44	5.7	5.5	5.3	5.4	5.5	5.4	5.4	44	200	120	120	70	70	80	70
45	6.6	5.8	6.7	R	R	R	R	45	270	160	280	R	R	R	R
46	6.3	6.7	R	R	R	R	R	46	290	210	R	R	R	R	R
47	5.9	5.7	5.7	5.6	R	R	R	47	330	200	130	120	R	R	R
48	6.3	6.3	5.4	R	R	R	R	48	270	210	120	R	R	R	R
49	6.2	6.3	6.4	5.9	5.7	R	R	49	260	240	150	130	90	R	R
50	6.7	6.6	6.6	6.8	6.8	6.6	R	50	320	320	250	230	160	120	R

L = Sample lost

R = Bedrock reached

(°) = degree

TABLE 3

Calcium Contents of Menagesha state forest soils

(in mg/100 gm)

Stand No.	Depth in cms.						
	0	10	20	30	40	50	60
1	838	650	541	409	463	354	303
2	848	473	395	496	R	R	R
3	370	741	508	443	553	454	R
4	623	302	336	321	326	298	243
5	782	530	457	R	R	R	R
6	738	1304	929	751	763	566	525
7	375	390	231	193	R	R	R
8	900	730	566	R	R	R	R
9	1126	972	690	R	R	R	R
10	101	173	136	130	194	191	207
11	158	193	166	175	167	208	185
12	109	131	137	202	168	192	170
13	96	125	77	121	126	115	128
14	130	190	178	R	R	R	R
15	L	523	256	224	203	166	115
16	729	649	209	258	237	R	R
17	715	155	176	236	136	118	289
18	774	311	257	353	292	266	R
19	187	804	401	385	479	333	R
20	316	889	535	350	243	250	R
21	1037	500	410	379	365	303	R
22	1214	705	744	L	534	427	230
23	801	L	232	290	262	276	263
24	389	441	309	274	R	R	R
25	641	315	243	136	132	R	R

Table 3 contd.
(Calcium)

Stand No.	Depth in cms.						
	0	10	20	30	40	50	60
29	310	206	137	167	182	R	R
30	304	L	398	360	341	280	R
31	L	507	356	354	R	R	R
32	371	342	336	345	429	R	R
33	234	262	177	181	171	156	R
34	380	406	251	218	222	R	R
35	631	599	333	243	250	289	R
36	L	332	359	297	272	124	R
37	1107	502	548	R	R	R	R
38	1209	921	606	542	R	R	R
39	496	483	310	270	293	297	R
40	278	191	95	142	166	227	R
41	230	257	276	227	227	206	R
42	219	126	135	161	218	180	118
43	246	240	150	80	205	192.	221
44	354	219	126	183	200	235	200
45	683	456	543	R	R	R	R
46	434	432	R	R	R	R	R
47	794	407	272	227	R	R	R
48	506	330	262	R	R	R	R
49	660	448	305	275	172	R	R
50	590	372	L	246	141	230	R

Table 3 Continued

Magnesium contents of Menagesha state forest soils (in mg/100 gm)

Stand No.	Depth in cms.						
	0	10	20	30	40	50	60
1	74	69	50	62	62	63	58
2	86	71	74	123	R	R	R
3	31	63	53	65	101	103	R
4	53	48	68	83	86	86	62
5	78	58	59	R	R	R	R
6	82	98	84	87	102	96	87
7	79	79	73	43	R	R	R
8	119	93	76	R	R	R	R
9	115	94	81	R	R	R	R
10	59	58	82	79	84	84	91
11	61	79	69	75	71	97	86
12	77	71	76	88	71	78	74
13	71	46	55	56	50	46	58
14	54	51	45	R	R	R	R
15	76	49	50	46	35	19	R
16	140	64	47	44	48	R	R
17	143	45	55	92	44	37	57
18	93	44	42	71	67	64	R
19	38	48	34	47	64	54	R
20	135	130	134	103	106	127	R
21	259	64	65	74	115	133	R
22	363	83	98	L	51	103	108
23	374	L	92	44	80	98	113
24	100	129	109	113	R	R	R
25	62	72	63	30	23	R	R
26	62	45	47	42	43	R	R
27	88	40	40	R	R	R	R
28	55	65	52	R	R	R	R

Table 3 contd.

(Magnessium)

Stand No.	Depth in cms.						
	0	10	20	30	40	50	60
29	76	64	40	38	55	R	R
30	99	L	95	53	70	74	R
31	93	92	100	R	R	R	R
32	69	69	70	65	81	R	R
33	94	82	74	77	73	79	R
34	55	74	61	60	57	R	R
35	95	73	67	68	59	91	R
36	L	47	43	23	20	41	R
37	383	98	138	R	R	R	R
38	217	127	36	56	R	R	R
39	54	57	84	101	160	134	R
40	79	57	53	60	59	74	R
41	48	56	63	54	54	74	R
42	41	44	45	41	46	50	30
43	55	57	35	29	54	39	65
44	71	48	29	40	44	52	46
45	104	92	88	R	R	R	R
46	91	90	R	R	R	R	R
47	55	52	70	58	R	R	R
48	73	58	73	R	R	R	R
49	110	96	78	76	R	R	R
50	89	72	67	57	77	R	R

Table 3 Continued

Potassium contents of Menagesha state forest soils
(in mg/100 gm)

Stand No.	Depth in cms						
	0	10	20	30	40	50	60
1	22.23	24.13	22.23	24.57	26.91	19.89	15.21
2	9.36	7.8	6.63	10.14	R	R	R
3	3.12	4.29	4.68	3.58	13.65	15.21	14.04
4	7.41	6.24	12.48	18.33	20.67	19.89	14.82
5	12.87	5.85	4.68	R	R	R	R
6	15.21	28.47	23.4	24.57	30.42	34.71	32.76
7	12.09	20.28	31.2	26.13	R	R	R
8	14.04	11.31	16.38	R	R	R	R
9	14.82	23.4	25.74	R	R	R	R
10	2.73	3.12	5.07	5.46	5.07	5.07	4.68
11	2.34	3.12	3.12	3.9	3.51	3.9	3.51
12	3.9	3.51	3.9	5.46	5.46	5.46	5.07
13	3.9	2.73	2.73	2.73	2.34	1.95	2.73
14	3.9	2.73	2.73	R	R	R	R
15	L	7.41	8.58	11.31	11.7	11.7	7.02
16	7.41	6.24	7.02	7.8	6.63	R	R
17	9.36	4.68	6.24	10.92	2.73	1.17	6.24
18	4.68	2.73	2.34	3.9	3.51	3.51	R
19	3.51	5.07	3.9	5.07	6.24	6.24	R
20	2.34	3.51	3.9	3.51	2.34	1.56	R
21	13.26	8.58	9.36	10.14	9.36	7.8	R
22	23.4	15.6	14.82	L	14.04	13.26	7.02
23	10.92	L	7.8	9.36	9.36	8.58	7.8
24	17.16	8.58	13.26	R	R	R	R
25	21.84	14.04	14.82	9.36	8.58	R	R
26	10.92	7.02	7.8	7.8	7.8	R	R
27	7.02	7.02	10.14	R	R	R	R
28	5.46	14.04	11.7	R	R	R	R

Table 3 contd.

(Potasium)

Stand No.	Depth in cms						
	0	10	20	30	40	50	60
29	10.92	6.24	3.12	7.8	10.14	R	R
30	5.46	L	10.14	5.46	6.24	5.46	R
31	L	17.94	18.72	19.5	R	R	R
32	11.7	7.8	9.36	9.36	13.26	R	R
33	3.9	5.46	3.12	3.12	3.12	3.12	R
34	7.02	4.68	4.68	3.9	3.12	R	R
35	8.58	7.8	13.26	10.92	9.36	13.26	R
36	L	9.36	10.14	10.14	11.7	12.48	R
37	12.48	19.5	20.28	R	R	R	R
38	10.92	17.16	17.94	23.4	R	R	R
39	7.8	9.36	9.36	10.14	15.6	17.16	R
40	12.48	10.92	9.36	8.58	7.8	10.14	R
41	11.7	9.36	10.14	10.14	9.36	7.8	R
42	3.9	6.24	6.24	6.24	7.02	6.25	4.68
43	11.7	9.36	6.24	4.68	7.02	7.02	7.8
44	13.26	9.36	6.24	8.58	7.8	9.36	7.8
45	13.26	18.72	22.62	R	R	R	R
46	17.16	17.16	R	R	R	R	R
47	9.36	9.36	16.38	16.38	R	R	R
48	13.26	10.92	9.36	R	R	R	R
49	20.28	21.06	20.28	20.28	16.38	R	R
50	6.24	8.58	L	11.7	9.36	15.6	R

Table 3 Continued

Sodium contents of Menagesha state forest soils

(in mg/100 gm)

Stand No.	Depth in cms						
	0	10	20	30	40	50	60
1	0.46	0.23	0.23	0.23	0.46	0.46	0.46
2	0.46	0.46	0.46	0.69	R	R	R
3	0.69	0.69	0.46	0.69	0.92	0.69	0.69
4	0.46	0.46	0.46	0.46	0.69	0.69	0.69
5	0.46	0.23	0.46	R	R	R	R
6	0.46	0.69	0.46	0.69	0.69	0.69	0.69
7	0.69	0.46	0.46	0.46	R	R	R
8	0.69	0.46	0.46	R	R	R	R
9	0.46	0.46	0.92	R	R	R	R
10	0.23	0.23	0.23	0.23	0.23	0.23	0.23
11	0.23	0.23	0.23	0.23	0.23	0.46	0.46
12	0.23	0.46	0.46	0.46	0.46	0.46	0.46
13	0.23	0.23	0.23	0.23	0.23	0.23	0.46
14	0.23	0.23	0.23	R	R	R	R
15	0.23	0.23	0.23	0.23	0.23	0.23	0.23
16	0.23	0.23	0.23	0.23	0.23	R	R
17	0.23	0	0	0	0	0.23	0
18	0.23	0	0	0	0	0	R
19	0	0	0	0	0.23	0.23	R
20	0.23	0.23	0.23	0.23	0.23	0.69	R
21	0.46	0	0	0.46	0.46	R	R
22	0.46	0.46	0.46	L	0.46	0.46	0.46
23	0.46	L	0.46	0.46	0.46	0.46	0.92
24	0.46	0.46	0.46	R	R	R	R
25	0.92	0.92	0.92	0.46	0.92	R	R.
26	0.92	0.92	0.92	0.92	1.38	R	R
27	0.46	0.92	0.92	R	R	R	R
28	0.92	0.46	0.46	R	R	R	R

Table 3 contd.

(Sodium)

Stand No.	Depth in cms						
	0	10	20	30	40	50	60
29	0.46	0.92	0.92	1.38	1.84	R	R
30	0.46	L	0.46	0.92	1.38	0.46	R
31	L	0	0	0	R	R	R
32	0	0	0	0.46	0.46	R	R
33	0	0	0.46	0	0.46	0.46	R
34	0.46	0.46	0.46	0.46	0.46	R	R
35	0.46	0.46	0.46	0.46	0.46	0.92	R
36	L	0.46	0.46	0.46	0.46	0.46	R
37	0.46	0.46	0.46	R	R	R	R
38	0.46	0.46	0.46	0.46	R	R	R
39	0.46	0.46	0.46	0.46	0.46	0.46	R
40	0.46	0.46	0.92	0.92	0.92	0.92	R
41	0.46	0.46	0.46	0.46	0.92	1.38	R
42	0.92	0.92	0.92	0.92	0.92	0.92	0.92
43	0.92	0.92	0.92	0.92	0.92	0.92	0.46
44	0.46	0.46	0.92	0.92	0.92	0.92	0.46
45	0.46	0.46	0.46	R	R	R	R
46	0.46	0.46	R	R	R	R	R
47	0.46	0.46	0.46	0.46	R	R	R
48	0.46	0.46	0.46	R	R	R	R
49	0.46	0.46	0.46	0.46	0.46	R	R
50	0.46	0.46	L	0.46	0.46	0.46	R

CHAPTER 3.

C L A S S I F I C A T I O N

3.1. Litrature Review

Gilmour (1951) has summarized the aim and concepts of classification as follows:-

a. 'Classification is a fundamental prerequisite of all conceptual thought, whatever the subject material of that thought.'

b. 'The primary function of classification is to construct classes about which we can make inductive generalizations.'

e. 'The particular classes we construct always arise in connection with a particular purpose.'

d. 'The classification that we adopt for any set of objeects depends on the particular field in which we wish to make indüctive generalizations.'

e. 'Classifications could be either natural or artificial.'

d. It is clear from the above that there can not be one ideal and absolute scheme of classification for any particular set of objects, but that there must be always a number of classifications, differing in their basis according to the prupose for which they have been constructed. One classification may, of course, be more natural than another in the sense defined above, and if there is any other factor influencing a group of objects more powerfully than any other, then a classification based on that factor will be more natural-that is to say, useful for a greater number of generalizations than any other.

3.1.1. Why classify vegetation?

With increasing agricultural intensification, one of the dangers facing the world today is the removal of natural plant cover. This has in the past brought serious environmental consequences and will undeoubtedly repeat itself in the future if proper measures of management are not taken (Alexander, 1973). This is especially true of the tropical ecosystems, where the complexity of the ecological relationships between physical factors, natural biological communities, and the impact of man are not clearly known in depth. This lack of reliable information has remained a bottle neck for proper land use. Moreover tropical ecosystems are the most vulnerable of all ecosystems to disturbance (Alken et al, 1975).

In tropical forests, before any plan of exploitation and/or conservation is started, Webb et al (1967) suggested that four major problems be solved.

a. The categorization of the forest, either by ordination or classification.

b. The establishment of a procedure for allocating new sites to the existing categories, or for quickly recognizing them as not belonging to the existing categories.

c. The establishment of the extent to which the categories reflect environmental factors, and the nature and relative importance of the factors concerned.

d. The systematization of the existing knowledge relating known environments and management systems to yield of agricultural crops - so as to enable a decision as to whether the area is to remain a forest or to be put to agricultural use.

3.1.2. Classification of vegetation

Various methods and techniques of classifying natural communities have been known in the past and a variety of new techniques have been developed recently.

The older classificatory methods include Braun- Blanquet's (1951) system that uses a hierarchy of floristic association and other units defined by diagonostic species based on dominance, constancy and fidelity; Tansley's (1913-47) system based on dominance types; 'dominance types' being defined by one or two major species of the community; Clements' (1916) system based on succession; Poore's (1955) system based on forming vegetation groups around noda. In all these methods there is subjectivity. Following these procedures a worker selects and preestablishes communities which he thinks are uniform, and typical of the region and which occur frequently.

The more recent attempts at classification have been more objective, the classificatory unit (the community) being arrived at after statistical or numerical analyses are done. In an ecological context, classification gives units which can be named, and which are discontinuous by virtue of the named, and whkch are discontinuous by virtue of the fact that the method of extraction has imposed a discontinuity where none genuine necessarly existed

(Kershaw, 1967). Thus it would obviously include similar individuals in a given group and dissimilar individuals in different groups, similarity being based on the attributes (species if it is stands which are being classified). Most of the classificatory techniques which are discussed below try to identify discontinuity in the spectrum of similarity among the individuals and to use these discontinuties as boundaries. This process of identifying the discontinuity is termed 'maximization' (Tewolde, 1969).

Williams and Dale (1965) distingush between self-structuring and derived structuring methods of maximization. In self-structuring methods, a function of the relevant attributes is defined between pairs of individuals or among groups of individuals.

In Derived-structuring a function is defined between pairs of attributes based on their occurences in the individuals. One or more attributes are then chosen for which the function is maximum or minimum and the groups are defined with respect to the related attribute.

There are two kinds of classifications, polythetic and monothetic. According to Lambert et al (1964) and Pielou (1969), in polythetic classification the combination of all existing attributes is considered in forming groups while in a monothetic classification two groups are distingused by the presence of a single attribute in one and its absence in another. A self-structuring maximization involves overall similarity of individuals with respect to their attributes. Hence a group is definable in terms of (a function of) all the attributes. The classification is thus polythetic.

A derived structuring maximization could be used to select a definite number of attributes to define groups of individuals on the basis of whether the individuals contained them or not. Such a classification is thus monothetic. (Sneath, 1962) pointed out that a derived structuring method need not be monothetic, but a monothetic technique of classification necessarily uses a derived structuring maximization.

The maximization process could be divisive or agglomerative (Lambert et al, 1964 and Pielou 1969). A divisive method starts with the whole population and divides it into smaller groups which themselves can be further subdivided and the process continues until the subdivision produces the ultimate classes. In an agglomerative method, the process starts from individuals and combines those which are similar into units, the process continuing to combine similar units of individuals into higher categories.

There are some advantages in using divisive techniques rather than agglomerative ones. Firstly, a divisive technique of classification can be terminated at any convinient level while an agglomerative one require the whole classification process from the individuals to the whole set of individuals. Secondly, in agglomeration since the combination process is began with the lowest unit, where chance anomalies are likely to obscure true affinities, bad combination may be made at an early stage in the process, which will affect the subsequent combination (Pielou, 1969).

According to Lambert et al (1964) in either divisive or agglomerative classification, if one could follow a path through which groups at different level can be ranked in importance and a unique relationship is specified between any group and the entire population at any given level, the classification is hierarchical. If the path of division or agglomeration is not clear and if it only shows intergroup distances the method of classification is reticulate. With regard to the two methods, Williams and Dale (1965) commented that both hierarchical and reticulate classifications are used to study the inter group relations, although in reticulate classifications, this is achieved after the final groupings are done and there is thus no insight possible into higher level groupings of the final groups. Greig-Smith (1964), however has pointed out that more importance should be given to the final groupings than the paths (the course of subdivision) by which they are obtained, because the route by which a particular grouping is segeregated will depened on what other groupings are included in the samples.

Williams and Dale (1965) distingush between two types of maximization methods. If the maximization is effected by a given characteristic of its members, it is reffered to as internal. In contrast if the maximization is from external individuals or external attributes, it is reffered to as external.

A number of indices are used in maximization. Most indices used in self-structuring methods of maximization are variants of the Mahalanobis function of distance. This is a function of the total number of attributes the two individuals under consideration have minus the attribute they have in common. As an index for maximization Williams et al (1966) used information statistic, Williams and Lambert (1959) used chi-square and/or correlation coefficient and Goodal (1953) also used chi-square.

3.1.3. Choise of classificatory technique

From the previous discussions it is clear that there is a wide choise of classificatory technique. For the present study, association analysis developed by Williams and Lambert (1959) was used.

Association Analysis

In this technique the presence and absence data are analysed to asses homogeneity of the vegetation. This will involve compiling the collected data into a contingency table.

Species A

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

Where 'a' shows that the two species (A and B) occur together
'b' shows that only species B is present
'c' shows that only species A is present
'd' shows that both species (A and B) are absent
n = a+b+c+d

Chi-square indices (X^2) are then calculated for each pair of species.

$$X^2 = \frac{(a.d - d.c)^2}{(a+b)(c+d)(a+c)(b+d)}$$

The species at each level of division which had frequencies less than 5% or greator than 95% in the groups of stands considered should be ignored from the calculation inorder to eliminate the undue weight which its scarcity would create (Muller-Dombois, et al 1974; Tewolde, 1969).

The null hypothesis of Association Analysis is that there is no correlation between two given species in their occurence. If the null hypothesis is true all the occurences would be statistically independent of each other and the total chi-square would more or less be Zero. The species with the highest chi-square sum thus deviates most from a completely random distribution which means that this species has the highest degree of association be it positive or negative with other species. (Edwards 1973; Muller-Dombois et al 1974). This species with the highest sum of chi-squares was used to divide the group of stands into two groups one which contained it the other which did not contain it. The process was then repeated for each subgroup until a final set of more or less homogeneous groups was found.

After trying chi-square and some other indices related to it Williams and Lambert (1960) concluded that $(\frac{x^2}{n})^{½}$ was the most sensitive association index. Greig-Smith et al (1967) used $\frac{x^2}{n}$ as an index in classifying tropical rain forests and corrected misclassifications using principal components ordination. When the same data were classified using $(\frac{x^2}{n})^{½}$ they found that much of the misclassification they had when $\frac{x^2}{n}$ was used was automatically corrected.

However Muller-Dombois, et al (1974) pointed out that the parameter can only be used efficiently when computer facilities are available.

The Association Analysis computation was done at the University of Manchester Reginal Computer Centre. The index used was $\frac{x^2}{n}$ and not $(\frac{x^2}{n})^{1/2}$ which would have been preferred. The programme did not exclude the species which had frequencies less than 5% or greater than 95%. The preferred index could not be used and the rare or very frequent species could not be excluded because effective interaction with the Computer Center was not possible from this distance.

3.2. Results and Discussion

Figure 3 shows the dendrogram representing the Association Analysis classification. The Y-axis shows the highest x^2 sum for each division. On the X-axis are spread out the various groups identified by the presence or absence of the individual plant species with the highest chi-square sum. Since these stands are identified by the presence or absence of known species of plant then by observing the species that grow in environments similar with the analysed stands vegetation could be classified into the groups. However it should be remembered that a group of stands identified entirely by the absence of plant is likely to be heterogeneous since an absence could result from diverse reasons. When it is identified by the presence of a species alone then it is likely to owe its identity to homogeneity since the species must occur because the environment lies within its limits of tolerance. When a group is identified by the presence of some species and the absence of others its environment is still defined because it must be within the limits of tolerance of the species present.

From the dendrogram it is clear that 16 groups were identified. See Fig. 3, Table 4a, 4b and 7.

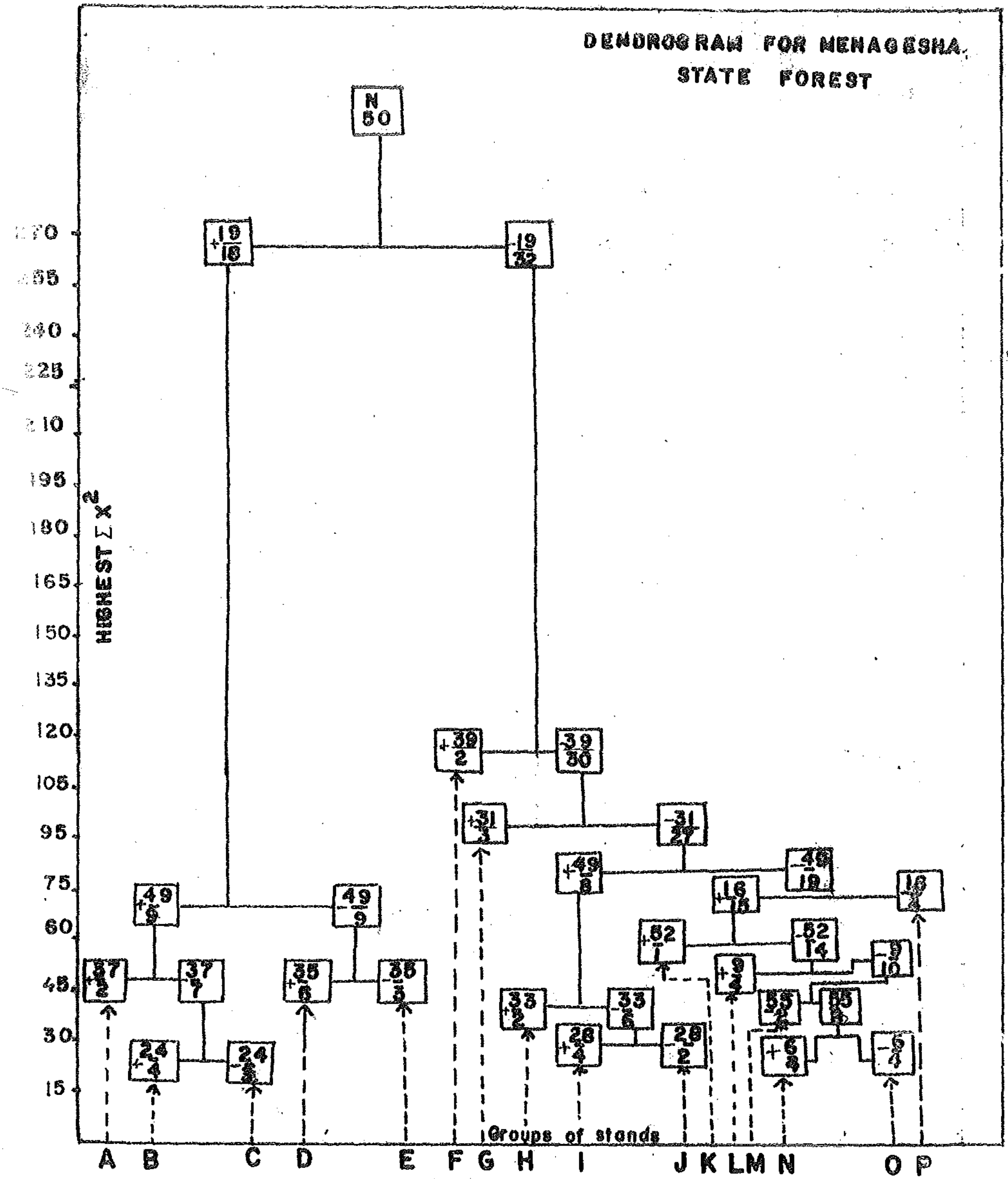
The vegetation thus was classified into more or less different homogeneous groups. The question that should follow is thus as to whether there is any relation between the distribution of the vegetation and the various environmental factors considered.

3.2.1. Interelationship between vegetation, soil and some other environmental factors

Many factors affect both the soil and the vegetation together. The microflora and microfauna and larger animals contribute to the maintainance and development of the soil and at the same time can affect the growth and development of the vegetation; the climate variables including temperature humidity and rainfall; geological factors and topography also affect the soil and thus also the vegetation. Moreover vegetation and soil affect one another (Langdale-Brown 1968). Taylor (1962) Longman et al (1974) discuss the influence of forests on the environment. Hopkins (1962) and many other scientists that have studied soils and/or plants have shown the necessity of soil for the development of vegetation cover. Thus it would not be surprising if the two phenomena are associated.

The other environmental factors considered have also relations with plant distribution.

Variation in soil pH, per se, does not directly influence plant growth, The very marked differences between the natural vegetations of acid and alkaline soils seem to arise either from differences in mineral nutrition or microflora (Etherington, 1975).



ASSOCIATION ANALYSIS GROUPS Fig.3

TABLE 4

Normal analysis information

Table 4a. Stand composition of groups

Group	Stand No.
A	33, 34
B	25, 26, 27, 28
C	11, 12, 29
D	13, 40, 41, 42, 43, 44
E	10, 17, 48
F	14, 50
G	30, 31, 32
H	15, 49
I	37, 45, 46, 47
J	38, 39
K	5
L	1, 2, 3, 6
M	21, 22
N	7, 9, 16, 35
O	4, 20, 23, 24
P	8, 18, 19, 36

Table 4b. Species used in dividing stands.

Species Number	Species Name
19	*Erica arborea*
49	*Rhus glutinosa*
37	*Nuxia congesta*
24	*Helichrysum cymosum*
35	*Myrica salicifolia*
39	*Osyris arborea*
31	Kolfa (mukeguracha)
33	*Maesa lanceolata*
28	*Jasminium abyssinicum*
15	*Dovyalis verrucosa*
52	*Rubus apetalus*
9	*Carrissa edulis*
55	*Senecio gigas*
6	*Bersama abyssinica*

Conductivity gives information on the total amount of water soluble salts present in the soil (Thompson, et al, 1978). Many of these salts are important plant nutrients. Conductivity would thus be expected to be correlated with vegetation.

Altitude shows variation in vegetation distribution. Temperature and atmospheric pressure change with altitude. As one goes from low to higher altitude, there is a decrease in temperature. The variation in temperature may result in changes in vegetation. Atmospheric pressure has some direct effect on plants. At higher altitudes there is lower atmospheric pressure which is accompanied by a decrease in carbondioxide which gives clues for the slow growth rate at higher altitude. (Hedberg, 1951, 1964; Lundgren, 1971).

Areas that have a steep slope are liable to soil leaching and increased surface runoff which will remove nutrients from the surface during times of high rainfall. Thus slope together with other environmental factors will determine the type of vegetation in an area (Moss, 1968 and Morison et al 1948).

The Menagesha State Forest supports a large biomass of coniferous and broad leaved trees. However, this does not necessarily mean that the soil supporting the vegetation is nutrient rich. Longman et al (1974) pointed out that the luxariant vegetation in the tropical forests does not arise from a soil which contains a high nutrient reserve, but because there is a fast circulation of nutrients between the soil and the vegetation and there is thus a maximum utilization of whatever nutrients exist in the ecosystem, which is mainly in the standing biomass. According one stand at that level of division. The assumption made is that there had been one stand where this species has been mistakenly punched as present. Since the computation was done abroad it has not yet been possible to check this error. The implication of this error on the whole analysis is however not likely to cause much distortion. Group F was therefore ignored from comparisons on the ground that it consisted of only one stand. Group K which consists of only one stand was likewise ignored.

Therefore, the remaining 14 groups of stands have been compared with one another for the means of their environmental factors. The comparisons were made using the t-test which deals with the problem of whether the observed difference between two sample means may be attributable to chance or whether it is likely to arise from real differences in the means (Steel et al, 1978). The t-test was performed for conductivity pH, cations (calcium, magnessium, potassium and sodium) of the soil surface and of the average of all the soil levels analysed. Altitude and slope were also similarly compared. Results are shown in table 5.

The first division for the 50 stands (see Fig. 3) was made by Erica arborea. 18 stands have E. arborea. These were subsequently divided into groups A, B, C, D, and E. The other 32 are without E. arborea and were grouped into F, G, H, I, J, K, L, M, N, O, and P. Means of the environmental factors for each group are given in Table 6.

3.2.2.1. The + Erica stands

Groups of stands with E. arborea have lower conductivities, pH, calcium and magnessium both at the soil surface and on the soil average than the - Erica stands. Potassium and sodium do not show distinct differences between + Erica and - Erica stands on the surface, but the + Erica stands have lower average potassium. Their statistical tests of significance with probabilities of 0.05 or lower are shown on table 5.

Low conductivity means that the soluble salts are available in small amounts. Low pH values according to Etherington (1975) have the effect of reducing the cation absorption capacity by competitive inhibition since H^+ ions occupy many sites of the uptake mechanism. Moreover, he has remarked that low pH soils are often coarse textued, and this, together with their low cation absorption capacity will render them leached easily. Easily mobilized elements e.g. calcium, magnessium, and potassium may thus be lost. Low pH in soils will also reduce the microbial activity, thus mineralization of the organic matter will be retarded (Buckman et al 1969).

In addition to the factors that contribute to the low nutrient status of the soils, the nature of the minerals of the bed-rock from which the nutrients are obtained will determine their availability. According to Thompson, et al (1978). Magnesium forming minerals (olivene, various incosilicates and biotite mica) are less resistant to weathering when compared with the calcium, potassium and sodium forming minerals. Thus severe weathering and soil erosion tend to reduce the magnesium content in the soil. Potassium forming minerals (muscovite micas; biotite mica and orthoclase feldspars) release potassium rapidly when there are environmental conditions that promote weathering. Potassium is released if the supply in the solution has been depleted, but it can reenter mineral structures if the solution concentration is high. Sodium forming feldspars weather more rapidly than potassium forming feldspars. Sodium that has been released to the soil solution is not subject to fixation and is less tightly held to cation exchange sites than potassium, magnesium and calcium. So it is the cation that is the most easily leached away. This can explain the eratic and small values of sodium in the Menagesha soil. As mentioned earlier the + Erica stands have low conductivities, pH and cations. The nonsignificant variation of surface potassium is probably because uptake of potassium by plants is so fast that its concentration is low at the surface (Lundgren, 1978 and Thompson, et al 1978). The significant variation in average potassium may be due to the fact that Menagesha is of a basaltic trachyte origin which is rich in potassium. The adaptation of + Erica stands in nutrient poor areas in the Menagesha State Forest is in agreement with the observations made by expedition participants to lake Wonchi (1974) where E. arborea was observed establishing itself on exposed rock with virtually no soil. Altitudnal variation as an environmental factor does not seem to determine the differences between the + Erica and - Erica types of vegetation since the t-test comparing the mean altitudes in the groups does not show significance. Comparatively the groups with E. arborea occupy less steep areas than the groups without E. arborea and this is shown in the significant comparisons with respect to slope (see Table 5.).

The + E. arborea stands were further subdivided by Rhus glutinosa. There are no environmental data that varied significantly between the groups where R. glutinosa is present and those from which it is absent.

Although there were no significant comparisons of environmental factors between the + E. arborea + R. glutinosa + N. congesta (A) and the + E. arborea + R. glutinosa - N. congesta (B and C) groups of stands. Groups B and C have lower conductivities at all levels. The average number of E. arborea shrubs perstand is only 4 in group A while it is 15 and 5 in groups B and C respectively and the average number of J. procera trees perstand is only 1 in group A while it is 12 and 8 in groups B and C respectively.

Some significant contrasts occurred among the final groups of the + E. arborea + R. glutinosa - N. congesta groups of stands i.e. between B and C. Group B has significantly higher sodium and potassium at all levels than group C. Although soil depth per se was not measured in each stand, soil samples were taken using an auger from surface, 10, 20, 30, 40, 50, and 60 cm. depths except when the bedrock was reached. Those stands where the bedrock was reached within 20 to 40 cm. depths were considered to have a shallow soil. Those that have depths of 40 cm. or more were considered as having a deeper soil. Since the nature of the bedrock is the same in both groups i.e. trachyte (Miller, et al, 1966) it can be presumed that the shallower soil of group B is younger than that of the deeper soil of group C. The younger soil would be expected to be less leached and thus higher in the monovalent cations. Since Helichrysum cymosum was the species that divide B and C this suggests that H. cymousum and the other species strongly positively associated with it either benefits from high levels of these cations or from some other environmental factor correlated with them.

Significant contrasts also occurred among the final groups of + E.arborea - R. glutinosa stands i.e. between D and E. Group E has higher conductivity pH, calcium, and magnesuim at all levels, the difference in average magnesium being significant. In contrast, group E is lower in potassium and sodium than group D, though these are not statistically significant. Since it was Myrica salicifolia which divided these groups, the suggestion is that this species and those strongly correlated with it do not benefit from increased magnesium, calcium, conductivity and pH.

3.2.2.2. The - Erica stands

For the - Erica group of stands subdivision was made by Osyris arborea followed by kolfa (mukeguracha). Kolfa (Mukeguracha)identifies group G which has significantly lower conductivity than groups I, L, M, N and P and lower calcium than I, L, M, N, and P. It also has low pH, magnesium and sodium. This indicates that its soil is the most leached. Since kolfa (Mukeguracha) identifies the group, the suggestion is that the species and other species that are positively associated with it can grow in soils that have low conductivities, pH and cations.

The next subdivision in the kolfa (Mukeguracha) stands was done by R. glutinosa followed by Maesa lanceolata. M. lanceolata identifies group H which has lower conductivity, pH, calcium, magnesium and sodium and higher surface potassium than groups I and J. The difference for sodium is statistically significant. The low conductivity, pH and cations except potassium could indicate that there is a higher leaching in the soil than that of groups I and J. The bedrock being the same for all the groups the higher potassium at the surface may be due to M. lanceolata or species that are positively associated with it add potassium to the surface. Potassium is a fast circulating nutrient between the plant and the soil (Thompson et al 1978).

There are no significant contrasts between the final groups of - E. arborea - O. arborea - kolfa (Mukeguracha) + R. glutinosa - M.lanceolata i.e. between I and J. However, these groups are found in significantly higher altitudes. Jasminium abyssinicum identifies group I. This group has an average soil depth of 20 cm. which is a shallower soil than group J that has an average soil depth of 40 cm. It is higher in conductivity, calcium, magnesium, potassium but low average pH. than group J, and occurs on a steeper slope. The combination of lower pH. and higher cations suggests that group I soils have higher organic matter than group J soils. The higher value of potassium may be due to the shallow potassium rich bedrock that will add potassium to the soil. This suggests that

J. abyssinicum and those species that are positively associated with it are adapted to grow on steep slope with shallow soils that have high organic matter and cations.

The next division in the - E. arborea - O. arbrea -Kolfa (Mukeguracha) - R. glutinosa group of stands was by Dovyalis verucosa, giving groups L, M, N, and O, which have the species, and group P from which it is absent. The soils in the + D. verucosa group of stands have a significantly higher sodium than group P. This suggests that D. verucosa and the other species that are positively associated with it benefit from increased sodium or other environmental factors associated with it.

The division of the + D. verucosa group of stands was on Rubus apetalus giving group K, which it will be remembered, has been left out of discussion, followed by Carissa edulis, giving group L in which it occurs, and groups M, N and O, from which it is absent. Group L has an average soil depth of 52 cm. It has higher conductivity, potassium and sodium, and a significantly higher pH than groups M, N and O, and occurs on a steeper slope. This shows that the soil is less leached than that of the -C. edulis group inspite of its deeper soil. Soils that are deeper are presumably older and should thus be leached more when compared with shallower and presumably younger soils. Since the deeper soil occurs on steeper slopes the leaching should be even more pronounced. Group L stands would thus be expected to be more leached and to have lower conductivity, pH and cations than groups M, N, and O. The results show that the reverse is true. The suggestion is that C. edulis and some other of the species that are positively associated with it have the ability to extract nutrients from deep down in the soil or even from the bedrock and release it on the soil surface in quantities more than balance the effects of leaching.

In the -C. edulis groups, subdivision was done by Senecio gigas which identifies group M. Group M has higher pH, calcium, magnesium and potassium than groups N and O, the difference in pH and calcium being statistically significant. The group has an average soil depth of 50 cm. and occurs in a flatter area. These factors show that group M soils are less leached than groups N and O soils. Since S. gigas identifies the group, the suggestion is, this species and other species that are positively associated with it may benefit from high pH and calcium, and other environmental factors associated with them. When compared with group L, the suggestion is further narrowed to a relatively flat area being preferred by.

Although there are no significant comparisons in - C. edulis - S. gigas final group of stands i.e. between groups N which is identified by the presence of Bersama abyssinica and group O by its absence, there are some observable differences. Group N has a higher conductivity and calcium, and low pH and magnesium.

Table

5a continued..

Groups Compared		Surface d.f.	Surface X_1-X_2	Surface t	Surface P	Average d.f.	Average X_1-X_2	Average t	Average P
	J	4	-170.0	2.7340	0.05	4	-126.34	3.9282	0.01
	L	6	-262.5	4.1386	0.005	6	-184.43	6.6483	0.0005
	M	4	-235.00	6.1187	0.005	4	-165.03	3.3792	0.025
	N	6	-262.5	5.6975	0.005	6	-169.39	4.1995	0.005
	O	6	-242.5	6.5448	0.0005	6	-123.00	2.8673	0.025
	P	6	-190.0	2.6264	0.025	6	-163.95	7.2701	0.0005
C to	D	7	-25.0	1.1735		7	-3.29	0.1611	
	E	4	-70.0	1.6551		4	-31.91	1.0239	
	F	3	-123.33	1.7040		3	-115.95	2.8994	0.05
	G	4	-20.0	1.0141		4	-81.23	3.0443	0.025
	H	3	-188.33	3.2611	0.025	3	-129.76	2.4642	0.05
	I	5	-116.13	3.4487	0.01	5	-164.7	3.3190	0.025
	J	3	-62.5	0.9994		3	-111.79	3.2422	0.025
	L	5	-120.59	1.8870		5	-169.88	5.5886	0.005
	M	3	-101.19	2.5817	0.05	3	-150.48	2.9861	0.05
	N	5	-105.55	2.2586	0.05	5	-154.84	3.6686	0.07
	O	5	-59.16	1.5623		5	-108.45	2.4283	0.05
	P	5	-100.11	1.3758		5	-149.4	7.5498	0.0005
D to	E	7	-45.0	1.1179		7	-28.62	0.8976	
	F	6	-98.33	1.3848		6	-112.66	2.7779	0.025
	G	7	5.0	0.3366		7	-77.94	2.8320	0.025
	H	6	-163.33	2.9024	0.025	6	-126.47	2.3823	0.05
	I	8	-90.41	2.9094	0.01	8	-161.41	3.2231	0.01
	J	6	-37.5	0.6130		6	-108.5	3.0883	0.025

5a continued..

Groups Compared		Surface				Average			
		d.f.	X_1-X_2	t	P	d.f.	X_1-X_2	t	P
	L	8	-95.59	1.5276		8	-166.59	5.3503	0.0005
	M	6	-76.19	2.0600	0.05	6	-147.19	2.8950	0.025
	N	8	-80.55	1.7942		8	-151.55	3.5457	0.005
	O	8	-34.16	0.9602		8	-105.16	2.3282	0.025
	P	8	-75.11	1.0490		8	-146.11	5.4894	0.0005
E to	F	3	-53.33	0.6678		3	-84.04	1.7922	
	G	4	50.00	1.2678		4	-49.32	1.3619	
	H	3	-118.33	1.7636		3	-97.85	1.6850	
	I	5	-125.83	2.6235	0.025	5	-132.79	2.3997	0.05
	J	3	-53.33	0.7484		3	-79.88	1.8886	
	L	5	-145.83	2.0125		5	-137.97	3.5347	0.01
	M	3	-118.33	2.2761		3	-118.57	2.1163	
	N	5	-145.83	2.5194	0.05	5	-122.93	2.5193	0.05
	O	5	-125.83	2.4675	0.05	5	-76.54	1.5028	
	P	5	-73.33	0.9123		5	-117.49	3.3065	0.025
G to	H	3	-168.33	3.0224		3	-48.53	0.8698	
	I	5	-175.83	5.8589	0.005	5	-83.47	1.5766	
	J	3	-103.33	1.7039		3	-30.56	0.7815	
	L	5	-195.83	3.1557	0.025	5	-88.65	2.4931	0.05
	M	3	-168.33	4.6633	0.01	3	-69.25	1.2904	
	N	5	-195.83	4.4340	0.005	5	-73.61	1.5980	
	O	5	-175.83	5.0742	0.005	5	-27.22	0.5633	
	P	5	-123.33	1.7335		5	-68.17	2.1521	0.05
H to	I	4	-7.5	0.1209		4	-34.94	0.5010	

5a continued

Groups Compared		Surface				Average			
		d.f.	X_1-X_2	t	P	d.f.	X_1-X_2	t	P
	J	2	65.0	0.7987		2	17.97	0.2999	
	L	4	-27.5	0.3336		4	-40.12	0.6958	
	M	2	0	0		2	-20.72	0.2948	
	N	4	-27.5	0.3930		4	-25.08	0.3878	
	O	4	-7.5	0.1165		4	21.31	0.3214	
	P	4	45.0	0.5029		4	-19.64	0.3548	
I to	J	4	72.5	1.0902		4	52.91	0.9239	
	L	6	-20.0	0.2950		6	-5.18	0.0943	
	M	4	7.5	0.1657		4	14.22	0.2089	
	N	6	-20.0	0.3852		6	9.86	0.1584	
	O	6	0	0		6	56.25	0.8801	
	P	6	52.5	0.6890		6	15.3	0.2916	
J to	L	4	-92.5	1.0773		4	-58.09	1.3921	
	M	2	-65.0	0.9358		2	-38.69	0.6678	
	N	4	-92.5	1.2504		4	-43.05	0.8444	
	O	4	-72.5	1.0550		4	3.34	0.0629	
	P	4	-20	0.2159		4	-37.61	0.9775	
L to	M	4	27.5	0.3890		4	19.4	0.3489	
	N	5	0	0		6	15.04	0.3113	
	O	6	20.0	0.2858		6	61.43	1.2172	
	P	6	72.5	0.7748		6	20.48	0.5874	
M to	N	4	-27.5	0.4941		4	-4.36	0.0694	
	O	4	-7.5	0.1548		4	42.03	0.6515	

5a continued

Groups Compared	Surface				Average			
	d.f.	X_1-X_2	T	P	d.f.	X_1-X_2	T	P
P	4	45	0.5711		4	1.08	0.0203	
N to O	6	20	0.3654		6	46.39	0.7951	
P	6	72.5	0.8756		6	5.44	0.1195	
O to P	6	52.5	0.6718		6	-40.95	0.8565	

Table 5b

Comparision of the groups of stands by Soil pH

(Using the t-test)

Groups Compared		Surface d.f.	Surface X_1-X_2	Surface t	Surface P	Average d.f.	Average X_1-X_2	Average t	Average P
A to	B	4	0.17	0.430		4	0.13	0.716	
	C	3	-0.10	-0.309		3	0.07	0.330	
	D	6	0.35	2.684	0.025	6	0.08	0.532	
	E	3	-0.07	-0.304		3	-0.15	-0.658	
	F	2	-0.40	-1.348		2	-0.85	-4.148	0.05
	G	3	0	0		3	-0.96	-3.709	
	H	2	-0.40	-2.025		2	-0.55	-1.886	
	I	4	-0.45	-1.919		4	-0.57	-2.430	0.05
	J	2	-0.4	-1.348		2	-0.99	-4.831	0.025
	L	4	-0.85	-4.148	0.01	4	-1.37	-8.338	0.0005
	M	2	-0.5	-2.532		2	-1.00	-6.086	0.025
	N	4	-0.18	-1.057		4	-0.73	-3.902	0.01
	O	4	-0.4	-1.661		4	-0.69	-3.919	0.01
	P	4	-0.15	-0.588		4	-0.8	-4.276	0.01
B to	C	5	-0.27	-0.528		5	-0.06	-0.346	
	D	8	-0.18	-0.433		8	-0.05	-0.516	
	E	5	-0.24	-0.525		5	-0.28	-1.456	
	F	4	-0.57	-1.154		4	-0.98	-5.964	0.005
	G	5	-0.17	-0.362		5	-1.09	-4.780	0.005
	H	4	-0.57	-1.291		4	-0.68	-2.570	0.05
	I	6	-0.62	-1.350		6	-0.7	-3.500	0.01

Table 5b Continued

Groups Compared	Surface d.f.	Surface X_1-X_2	Surface t	Surface P	Average d.f.	Average X_1-X_2	Average t	Average P
J	4	-170.0	2.7340	0.05	4	-126.34	3.9282	0.01
L	6	-262.5	4.1386	0.005	6	-184.43	6.6483	0.0005
M	4	-235.00	6.1187	0.005	4	-165.03	3.3792	0.025
N	6	-262.5	5.6975	0.005	6	-169.39	4.1995	0.005
O	6	-242.5	6.5448	0.0005	6	-123.00	2.8673	0.025
P	6	-190.0	2.6264	0.025	6	-163.95	7.2701	0.0005
C to D	7	-25.0	1.1735		7	-3.29	0.1611	
E	4	-70.0	1.6551		4	-31.91	1.0239	
F	3	-123.33	1.7040		3	-115.95	2.8994	0.05
G	4	-20.0	1.0141		4	-81.23	3.0443	0.025
H	3	-188.33	3.2611	0.025	3	-129.76	2.4642	0.05
I	5	-116.13	3.4487	0.01	5	-164.7	3.3190	0.025
J	3	-62.5	0.9994		3	-111.79	3.2422	0.025
L	5	-120.59	1.8870		5	-169.88	5.5886	0.005
M	3	-101.19	2.5817	0.05	3	-150.48	2.9861	0.05
N	5	-105.55	2.2586	0.05	5	-154.84	3.6686	0.07
O	5	- 59.16	1.5623		5	-108.45	2.4283	0.05
P	5	-100.11	1.3758		5	-149.4	7.5498	0.0005
D to E	7	-45.0	1.1179		7	-28.62	0.8976	
F	6	-98.33	1.3848		6	-112.66	2.7779	0.025
G	7	-5.0	0.3366		7	-77.94	2,8320	0.025
H	6	-163.33	2.9024	0.025	6	-126.47	2.3823	0.05
I	8	-90.41	2.9094	0.01	8	-161.41	3.2231	0.01
J	6	-37.5	0.6130		6	-108.5	3.0883	0.025
L	8	-95.59	1.5276		8	-166.59	5.3503	0.0005

Table 5b Continued

Groups Compared		Surface				Average			
		d.f.	X_1-X_2	t	P	d.f.	X_1-X_2	t	P
	M	6	-76.19	2.0600	0.05	6	-147.19	2.8950	0.025
	N	8	-80.55	1.7942		8	-151.55	3.5457	0.005
	O	8	-34.16	0.9602		8	-105.16	2.3282	0.025
	P	8	-75.11	1.0490		8	-146.11	5.4894	0.0005
E to	F	3	-53.33	0.6678		3	-84.04	1.7922	
	G	4	50.00	1.2678		4	-49.32	1.3619	
	H	3	-118.33	1.7636		3	-97.85	1.6850	
	I	5	-125.83	2.6235	0.025	5	-132.79	2.3997	0.05
	J	3	-53.33	0.7484		3	-79.88	1.8886	
	L	5	-145.83	2.0125		5	-137.97	3.5347	0.01
	M	3	-118.33	2.2761		3	-118.57	2.1163	
	N	5	-145.83	2.5194	0.05	5	-122.93	2.5193	0.05
	O	5	-125.83	2.4675	0.05	5	-76.54	1.5028	
	P	5	-73.33	0.9123		5	-117.49	3.3065	0.025
G to	H	3	-168.33	3.0224		3	-48.53	0.8698	
	I	5	-175.83	5.8589	0.005	5	-83.47	1.5766	
	J	3	-103.33	1.7039		3	-30.56	0.7815	
	L	5	-195.83	3.1557	0.025	5	-88.65	2.4931	0.05
	M	3	-168.33	4.6633	0.01	3	-69.25	1.2904	
	N	5	-195.83	4.4340	0.005	5	-73.61	1.5980	
	O	5	-175.83	5.0742	0.005	5	-27.22	0.5633	
	P	5	-123.33	1.7335		5	-68.17	2.1521	0.05
H to	I	4	-7.5	0.1209		4	-34.94	0.5010	
	J	2	65.0	0.7987		2	17.97	0.2999	
	L	4	-27.5	0.3336		4	-40.12	0.6958	

Table 5b Continued

Groups Compared		Surface d.f.	Surface X_1-X_2	Surface t	Surface P	Average d.f.	Average X_1-X_2	Average t	Average p
	M	2	0	0		2	-20.72	0.2948	
	N	4	-27.5	0.3930		4	-25.08	0.3878	
	O	4	-7.5	0.1165		4	21.31	0.3214	
	P	4	-45.0	0.5029		4	-19.64	0.3548	
I to	J	4	72.5	1.0902		4	52.91	0.9239	
	L	6	-20.0	0.2950		6	-5.18	0.0943	
	M	4	7.5	0.1657		4	14.22	0.2089	
	N	6	-20.0	0.3852		6	9.86	0.1584	
	O	6	0	0		6	56.25	0.8801	
	P	6	52.5	0.6890		6	15.3	0.2916	
J to	L	4	-92.5	1.0773		4	-58.09	1.3921	
	M	2	-65.0	0.9358		2	-38.69	0.6678	
	N	4	-92.5	1.2504		4	-43.05	0.8444	
	O	4	-72.5	1.0550		4	3.34	0.0629	
	P	4	-20	0.2159		4	-37.61	0.9775	
L to	M	4	27.5	0.3890		4	19.4	0.3489	
	N	6	0	0		6	15.04	0.3113	
	O	6	20.0	0.2858		6	61.43	1.2172	
	P	6	72.5	0.7748		6	20.48	0.5874	
M to	N	4	-27.5	0.4941		4	-4.36	0.0694	
	O	4	-7.5	0.1548		4	42.03	0.6515	
	P	4	45	0.5711		4	1.08	0.0203	
N to	O	6	20	0.3654		6	46.39	0.7951	
	P	6	72.5	0.8756		6	5.44	0.1195	
O to	P	6	52.5	0.6718		6	-40.95	0.8565	

Table 5c

Comparisons of the groups of stands bu soil Calcium using the t-test.

Groups Compared	Surface d.F	Surface $\bar{X}_1-\bar{X}_2$	Surface t	Surface P	Average d.F	Average $\bar{X}_1-\bar{X}_2$	Average t	Average P
A to B	4	-17.25	-0.134		4	33.07	0.548	
C	3	88.0	1.018		3	50.39	1.028	
D	6	69.83	0.865		6	50.66	1.022	
E	3	-160.33	-0.934		3	6.00	-0.078	
F	2	78.00	0.358		2	-14.16	-0.180	
G	3	-30.5	-0.391		3	-121.05	-2.134	
H	2	-353.0	-4.836	0.025	2	-70.12	-0.477	
I	4	-447.5	-0.350		4	-234.44	-2.056	
J	2	-545.5	-1.499		2	-265.66	-1.577	
L	4	-362.75	-2.703	0.05	4	-215.97	-2.721	0.05
M	2	-818.5	-7.134	0.01	2	-296.47	-1.403	
N	4	-533.25	-4.100	0.01	4	-198.66	-1.528	
O	4	-225.25	-1.696		4	-128.85	-1.648	
P	4	-313.33	-1.539		4	-179.16	-2.101	
B to C	5	-105.25	-1.100		5	17.32	0.452	
D	8	87.08	0.780		8	17.59	0.452	
E	5	-143.08	-0.760		5	-39.07	-0.551	
F	4	-60.75	-0.263		4	-47.23	-0.696	
G	5	-13.25	-0.121		5	-154.12	-3.336	0.025
H	4	-335.75	-3.164	0.025	4	-102.90	-0.716	
I	6	-430.25	-2.454	0.025	6	-276.51	-2.417	0.05
J	4	-528.25	-1.420		4	-298.73	-1.804	
L	6	-345.5	-2.233	0.05	6	-249.04	-3.422	0.01
M	4	-801.25	-5.798	0.005	4	-329.54	-1.576	
N	6	-516.00	-3.414	0.01	6	-231.73	-1.834	
O	6	-208.00	-1.355		6	-161.92	-2.251	0.05
P	6	-296.08	-1.360		6	-212.23	-2.666	0.025
C to D	7	-18.17	-0.314		7	0.27	-0.016	
E	4	-248.33	-1.532		4	-56.39	-0.316	
F	3	-166.00	-0.790		3	-64.55	-1.114	

Table 5c (Continued)

Groups Compared		Surface d.F	Surface $\bar{X}_1-\bar{X}_2$	Surface t	Surface p	Average d.F	Average $\bar{X}_1-\bar{X}_2$	Average t	Average p
	G	4	-118.5	-2.201	0.05	4	-171.44	-5.742	0.005
	H	3	-441.0	-9.510	0.005	3	-120.51	-0.865	
	I	5	-535.5	-3.642	0.01	5	-568.72	-5.226	0.005
	J	3	-633.5	-1.762		3	-666.72	-4.120	0.025
	L	5	-450.75	-3.702		5	-403.97	-7.543	0.005
	M	3	-906.5	-9.073	0.005	3	-939.72	-4.559	0.01
	N	5	-621.25	-5.301	0.01	5	-654.47	-5.394	0.01
	O	5	-313.25	-2.605	0.025	5	-346.47	-5.527	0.005
	P	5	-401.33	-2.051	0.05	5	-434.55	-6.089	0.005
D to	E	7	-230.16	-1.446		7	-56.66	-0.915	
	F	6	-147.83	-0.711		6	-64.82	-1.111	
	G	7	-100.33	-2.279	0.05	7	-171.71	-5.522	0.0005
	H	6	-422.83	+12.257	0.0005	6	-120.78	-0.866	
	I	8	-517.33	-3.599	0.005	8	-294.1	-2.697	0.025
	J	6	-615.33	-1.718		6	-316.32	-1.953	
	L	8	-432.58	-3.674	0.005	8	-266.63	-4.130	0.005
	M	6	-888.33	-9.352	0.0005	6	-347.13	-1.683	
	N	8	-603.08	-5.336	0.0005	8	-249.32	-2.051	0.05
	O	8	-295.08	-2.539	0.025	8	-179.51	-2.845	0.025
	P	8	-383.16	-1.984		8	-229.82	-3.204	0.01
E to	F	3	82.33	0.320		3	-8.16	-0.098	
	G	4	129.83	0.823		4	-115.05	-1.724	
	H	3	-192.67	-1.240		3	64.12	0.423	
	I	5	-237.17	-1.375		5	-237.44	-1.913	
	J	3	-385.17	-0.990		3	-259.66	-1.506	
	L	5	-202.42	-1.055		5	-209.97	-2.396	0.05
	M	3	-658.17	-3.681	0.025	3	-290.47	-1.354	
	N	5	-372.92	-1.973		5	-192.66	-1.425	
	O	5	-64.92	-0.340		5	-122.85	-1.419	
	P	5	-153.00	-0.623		5	-173.16	-1.861	

Table 5c (Continued)

Groups Compared	Surface d.F	Surface $\bar{X}_1-\bar{X}_2$	Surface t	Surface p	Average d.F	Average $\bar{X}_1-\bar{X}_2$	Average t	Average p
G to H	3	-322.5	-11.789	0.005	3	50.93	0.359	
I	5	-417.0	-2.933	0.025	5	-122.39	-1.094	
J	3	-515.0	-1.440		3	-144.61	-0.882	
L	5	-332.25	-2.868	0.025	5	- 94.92	-1.372	
M	3	-788.0	-8.507	0.005	3	-175.42	-0.844	
N	5	-502.75	-4.527	0.005	5	- 77.61	-0.626	
O	5	-194.75	-1.704		5	- 8.8	-0.116	
P	5	-282.83	-1.473		5	-58.11	-0.766	
H to I	4	-99.5	-0.678		4	-173.32	-0.984	
J	2	-192.5	-0.540		2	-195.54	-0.918	
L	4	-9.75	-0.087		4	-145.85	-0.956	
M	2	-465.5	-5.260	0.025	2	-226.35	-0.911	
N	4	-180.25	-1.675		4	-128.54	-0.698	
O	4	-127.75	-1.151		4	-58.73	-0.386	
P	4	-39.67	-0.209		4	-109.04	-0.700	
I to J	4	-98.0	-0.256		4	-22.22	-0.114	
L	6	84.75	0.473		6	27.47	0.219	
M	4	-377.0	-2.245	0.05	4	-53.03	-0.228	
N	6	-85.75	-0.487		6	44.78	0.276	
O	6	222.25	1.247		6	114.59	0.919	
P	6	134.17	0.569		6	64.28	0.497	
J to L	4	132.75	0.489		4	49.69	0.237	
M	2	-273.00	-0.743		2	-30.81	-0.118	
N	4	12.25	0.633		4	67.0	0.332	
O	4	320.25	0.858		4	136.81	0.791	
P	4	232.17	0.575		4	86.50	0.776	
L to M	4	-455.75	-3.182	0.025	4	-80.5	-0.373	
N	6	-170.5	-1.095		6	17.31	0.127	
O	6	137.5	0.370		6	87.12	0.985	
P	6	49.42	0.224		6	26.81	0.388	
M to N	4	285.25	2.047		4	97.81	0.410	
O	4	593.25	4.180	0.01	4	167.62	0.780	
P	4	505.17	2.409	0.05	4	117.31	0.539	
N to O	6	308.0	1.992		6	69.81	0.514	
P	6	219.92	1.007		6	19.5	0.139	
[illegible]	[illegible]	[illegible]	[illegible]		6	50.31	0.536	

Table 5d

Comparisons of the Groups of stands by Soil-Manenium

(using the t-test)

Groups Compared		Surface				Average			
		d.f.	X_1-X_2	t	P	d.f.	X_1-X_2	t	P
A to	B	4	12.75	0.786		4	24.56	3.518	0.025
	C	3	8.17	0.531		3	.84	0.121	
	D	6	18.67	1.186		6	21.83	4.299	0.005
	E	3	-12.17	-0.409		3	1.58	0.174	
	F	2	8.00	0.352		2	8.31	1.035	
	G	3	-7.5	-0.437		3	-4.47	-0.577	
	H	2	-13.5	-0.604		2	15.5	0.801	
	I	4	-80.0	-1.023		4	-20.72	-0.899	
	J	2	-56.0	-0.676		2	-49.59	-1.580	
	L	4	11.25	0.584		4	-4.72	-0.734	
	M	2	-231.00	-4.279	0.05	2	-48.45	-0.800	
	N	4	-27.75	-1.417		4	-1.74	-0.147	
	O	4	-86.00	-1.179		4	-32.33	-2.224	0.05
	P	4	-3.83	-0.152		4	16.17	-1.964	
B to	C	5	-4.58	-0.513		5	-23.72	-2.732	0.025
	D	8	5.92	0.622		8	-2.73	-0.375	
	E	5	-24.92	-0.924		5	-22.98	-2.195	0.05
	F	4	-4.75	-0.251		4	-16.25	-1.638	
	G	5	-20.25	-1.730		5	-29.03	-3.109	0.025
	H	4	-26.25	-1.420		4	-9.06	-0.452	
	I	6	-92.75	-1.202		6	-45.28	-1.917	

5d continued..

Groups Compared	Surface d.f.	Surface X_1-X_2	Surface t	Surface P	Average d.f.	Average X_1-X_2	Average t	Average P
J	4	-68.75	-0.840		4	-74.15	-2.331	0.05
L	6	-1.5	-0.103		6	-29.28	-3.538	0.01
M	4	-244.25	-4.652	0.005	4	-73.01	-1.202	
N	6	-40.50	-2.692	0.025	6	-26.30	-2.032	0.05
O	6	-98.75	-1.374		6	-56.89	-3.684	0.01
P	6	-16.58	-0.756		6	-8.39	-0.861	
C to D	7	10.5	1.308		7	20.99	3.794	0.005
E	4	-20.34	-0.768		4	.74	0.079	
F	3	-.17	-0.658	0.005	3	7.47	0.837	
G	4	-15.67	-1.488		4	-5.31	-0.659	
H	3	-21.67	-1.220		3	14.66	0.753	
I	5	-88.17	-1.144		5	-21.56	-0.932	
J	3	-64.17	-0.786		3	-50.43	-1.603	
L	5	3.08	0.225		5	-5.56	-0.819	
M	3	-239.67	-4.586	0.01	3	-49.29	-0.814	
N	5	-35.92	-2.539	0.05	5	-2.58	-0.214	
O	5	-94.17	-1.314		5	-33.17	-2.256	0.05
P	5	-12.00	-0.563		5	15.33	1.799	
D to E	7	-30.84	-1.155		7	-20.25	-2.515	0.025
F	6	-10.67	-0.575		6	-13.52	-1.975	
G	7	-26.17	-2.372	0.025	7	-26.30	-4.039	0.005
H	6	-32.17	-1.780		6	-6.33	-0.335	
I	8	-98.67	-1.280		8	-42.55	-1.872	

5d continued....

Groups Compared		Surface				Average			
		d.f.	X_1-X_2	t	P	d.f.	X_1-X_2	t	P
	J	6	-74.67	-0.914		6	-71.42	-2.296	0.05
	L	8	-7.67	-0.545		8	-26.55	-5.454	0.0005
	M	6	-250.17	-4.778	0.005	6	-70.28	-1.164	
	N	8	-46.42	-3.195	0.01	8	-23.57	-2.128	0.05
	O	8	-104.67	-1.459		8	-54.16	-3.892	0.005
	P	8	-22.50	-1.043		8	-5.66	-0.799	
E to	F	3	20.17	0.644		3	6.73	0.661	
	G	4	4.67	0.169		4	-6.05	-0.608	
	H	3	-1.33	-0.043		3	13.92	0.684	
	I	5	-67.83	-0.836		5	-22.30	-0.934	
	J	3	-43.83	-0.512		3	-51.17	-1.599	
	L	5	23.42	0.810		5	-6.3	-0.703	
	M	3	-219.33	-3.773	0.01	3	-50.03	-0.822	
	N	5	-15.58	-0.536		5	-3.32	-0.248	
	O	5	-73.83	-0.971		5	-33.91	-2.143	0.05
	P	5	8.34	0.251		5	14.59	1.411	
G to	H	3	-6.0	-0.312		3	19.97	1.009	
	I	5	-72.5	-0.937		5	-16.25	-0.695	
	J	3	-48.5	-0.591		3	-45.12	-1.426	
	L	5	18.75	1.199		5	-.25	-0.033	
	M	3	-224.00	-4.242	0.025	3	-43.98	-0.725	
	N	5	-20.25	-1.262		5	2.73	0.218	
	O	5	-78.50	-1.089		5	-27.86	-1.845	
	P	5	3.67	0.177		5	20.64	2.246	0.05

5d contiued...

Groups Compared	Surface				Average			
	d.f.	X_1-X_2	t	P	d.f.	X_1-X_2	t	P
H to I	4	-66.50	-0.845		4	-36.22	-1.234	
J	2	-42.50	-0.510		2	-65.09	-1.794	
L	4	24.75	1.168		4	-20.22	-1.048	
M	2	-218.00	-3.985	0.05	2	-63.95	-1.012	
N	4	-14.25	-0.663		4	-17.24	-0.794	
O	4	-72.50	-0.986		4	-47.83	-2.054	
P	4	9.67	0.361		4	.67	0.033	
I to JJ	4	24.0	0.214		4	-28.87	-0.752	
L	6	91.25	1.171		6	16.0	0.696	
M	4	-151.50	-1.632		4	-27.73	-0.430	
N	6	52.25	0.670		6	18.98	0.758	
O	6	-6.00	-0.057		6	-11.61	-0.439	
P	6	76.17	0.957		6	36.89	1.566	
J to L	4	67.25	0.815		4	44.87	1.431	
M	2	-175.50	-1.815		2	1.14	0.017	
N	4	28.25	0.342		4	47.85	1.455	
O	4	-30.00	-0.277		4	17.26	0.508	
P	4	52.17	0.620		4	65.76	2.070	
L to M	4	-242.75	-4.536		4	-43.73	-0.723	
N	6	-39.00	-2.134	0.05	6	2.98	0.253	
O	6	-97.25	-1.339		6	-27.61	-1.909	
P	6	-15.08	-0.622		6	20.89	2.577	0.025
M to N	4	203.75	3.798	0.01	4	46.71	0.762	

5d continued

Groups Compared	Surface				Average			
	d.f.	X_1-X_2	t	P	d.f.	X_1-X_2	t	d
O	4	145.50	1.646		4	16.12	0.260	
P	4	227.67	4.068	0.01	4	64.62	1.064	
N to O	6	-58.25	-0.801		6	-30.59	-1.742	
P	6	23.92	0.976		6	17.91	1.396	
O to P	6	82.17	1.104		6	48.5	3.159	0.01

Table 5H (Contiuned)

Groups compared		Surface			
		d.F	$\bar{X}_1-\bar{X}_2$	t	p
	N	4	-4.75	2.6430	0.05
	O	4	-1.00	0.5110	
	P	4	-3.75	1.3359	
I to	J	4	4.25	0.3910	
	L	6	2.25	0.5529	
	M	4	8.75	1.4387	
	N	6	4.5	1.5025	
	O	6	8.25	2.6668	0.025
	P	6	5.5	1.4903	
J to	L	4	-2.00	0.3934	
	M	2	4.5	0.6615	
	N	4	0.25	0.0585	
	O	4	4.00	0.9214	
	P	4	1.25	0.2612	
L to	M	4	6.5	1.0266	
	N	6	2.25	0.6476	
	O	6	6.00	1.6856	
	P	6	3.25	0.7948	
M to	N	4	-4.25	0.7455	
	O	4	-0.5	0.0869	
	P	4	-3.25	0.5332	
N to	O	6	3.75	1.6638	
	P	6	1.00	0.3310	
O to	P	6	2.75	0.3816	

Table 6 Mean Values of Environmental Factors

Groups	Conductivity (mm hos)		pH		Calcium (mg/100 gm)		Magnessium (mg/100 gm)		Potassium (mg/100 gm)	
	Surface	Average	Surface	Average	Surface	Average	Surface	Average	Surface	Aver
A	135.0	85.0	6.0	5.6	300.0	236.1	79.5	72.9	5.4	4
B	80.0	62.8	5.8	5.5	324.2	203.1	66.7	48.3	11.3	9
C	126.6	77.3	6.1	5.5	219.0	185.7	71.3	72.0	5.7	4
D	151.6	80.5	5.6	5.5	237.1	185.5	60.8	51.0	9.4	7
E	196.6	109.2	6.0	5.7	476.3	242.1	91.6	71.3	8.4	5
G	146.6	158.6	6.0	6.6	337.5	357.2	87.0	77.3	8.5	10
H	77.7	71.9	6.4	6.1	660.0	306.2	93.0	57.4	20.2	13.
I	322.5	252.0	6.4	6.2	754.5	479.6	159.5	93.6	13.0	16.
J	250.0	189.1	6.4	6.6	852.5	501.8	135.5	122.5	9.3	14.
L	342.5	247.2	6.8	7.0	669.7	452.1	68.2	77.6	12.4	18.
M	315.0	227.8	6.5	6.6	1125.5	532.6	311.0	121.3	13.3	11.
N	342.5	232.2	6.1	6.3	840.2	434.8	107.2	74.6	10.7	13.
O	322.5	135.8	6.4	6.3	532.2	365.0	165.5	105.2	9.4	9.
P	270.0	226.7	6.1	6.4	620.3	415.3	83.3	56.7	7.4	7.

Table 5e
Comparisons of the groups of
Stands by Soil potassium
(Using of the t-test)

Groups Compared	Surface				Average			
	d.F	$\bar{X}_1-\bar{X}_2$	t	p	d.F	$\bar{X}_1-\bar{X}_2$	t	p
A to B	4	-5.85	-1.458		4	-5.91	-5.852	0.00
C	3	-0.26	-o.085		3	-0.88	-0.943	
D	6	-4.03	-1.700		6	-3.23	-3.807	0.005
E	3	-2.99	-0.868		3	-1.83	-1.294	
F	2	0.39	0.200		2	-4.85	-1.604	
G	3	-3.12	-1.045		3	-6.10	-3.421	0.025
H	2	-14.82	-9.488	0.01	2	-9.89	-3.378	0.05
I	4	-7.61	-3.397	0.025	4	-12.31	-8.030	0.065
J	2	-3.9	-1.765		2	-10.26	-4.753	0.025
L	4	-7.02	-1.607		4	-14.04	-6.181	0.005
M	2	-12.87	-2.426		2	-1.66	-3.842	0.05
N	4	-5.27	-2.289	0.05	4	-9.41	-4.575	0.01
O	4	-4.0	-1.048		4	-5.59	-5.082	0.005
P	4	-1.95	-0.594		4	-3.24	-4.254	0.01
B to C	5	5.59	1.231		5	5.03	5.273	0.005
D	8	1.82	0.444		8	2.68	3.074	0.01
E	5	2.86	0.595		5	4.08	2.857	0.025
F	4	6.24	1.610		4	1.06	0.350	

Table 5e (Continued)

	G	5	2.73	0.608		5	-0.19	-0.106	
	H	4	-8.97	-2.428		4	-3.98	-1.356	
	I	6	-1.76	-0.437		6	-6.4	-4.140	0.005
	J	4	1.95	0.486		4	-4.35	-2.607	
	L	6	-1.17	-0.213		6	-8.13	-3.565	0.025
	M	4	-7.02	-1.119		4	-1.75	-0.693	
	N	6	0.58	0.143		6	-3.50	-1.694	
	O	6	1.85	0.383		6	0.32	0.286	
	P	6	3.9	0.832		6	2.67	3.391	0.01
C to	D	7	-3.77	-1.184		6	-2.35	-3.009	0.025
	E	4	-2.73	-0.674		7	-0.95	-0.691	
	F	3	0.65	0.225		4	-3.97	-1.321	
	G	4	-2.86	-0.780		3	-5.22	-2.979	0.05
	H	3	-14.56	-5.519	0.005	4	-9.01	-3.098	0.025
	I	5	-7.35	-2.380	0.05	5	-11.43	-7.637	0.0005
	J	3	-3.64	-1.187		3	-9.38	-4.397	0.025
	L	5	-6.76	-1.391		5	-13.16	-5.856	0.005
	M	3	-12.61	-2.207	0.05	3	-6.78	-2.716	0.025
	N	5	-5.01	1.599		5	-8.53	-4.202	0.005
	O	5	-3.74	-0.916		5	-4.71	-4.491	0.005
	P	5	-1.69	-0.432		5	-2.36	3.442	0.01
D to	E	7	1.04	0.293		7	1.4	1.061	
	F	6	4.42	2.070		6	-1.62	-0.544	
	G	7	0.91	0.293		7	-4.49	-2.628	0.025
	H	6	-10.79	-6.051	0.0005	6	-8.28	-2.872	0.025
	I	8	-3.58	-1.492		8	-10.7	-7.401	0.0005

Table 5e (Continued)

J	6	0.13	0.055		6	-8.65	-4.124	0.005
L	8	-2.99	-0.671		8	-12.43	-5.615	0.0005
M	6	-8.84	-1.645		6	-6.05	-2.454	0.025
N	8	-1.24	-0.505		8	-7.8	-3.915	0.005
O	8	0.03	0.008		8	-3.98	-4.083	0.005
P	8	2.08	0.613		8	-1.63	-2.882	0.025
E to F	3	3.38	1.028		3	-3.02	-0.947	
G	4	-0.13	-0.033		4	-4.27	-2.084	
H	3	-11.83	-3.852	0.025	3	-8.06	-2.603	0.05
I	5	-4.62	-1.333		5	-10.48	-5.709	0.005
J	3	-0.91	-0.264		3	-8.43	-3.537	0.025
L	5	-4.03	0.789		5	-12.21	-4.912	0.005
M	3	-9.88	-1.6[illegible]7		3	-5.83	-2.149	
N	5	-2.28	-0.650		5	-7.58	-3.308	0.025
O	5	-1.01	-0.231		5	-3.76	-2.518	0.05
P	5	1.04	0.247		5	-1.41	-1.115	
G to H	3	-11.7	-4.596		3	-3.79	-1.155	
I	5	-4.49	-1.491		5	-6.21	-2.911	0.025
J	3	-0.78	-0.261		3	-4.16	-1.588	
L	5	-3.9	-0.811		5	-7.94	-2.927	0.025
M	3	-9.75	-1.719		3	-1.56	-0.534	
N	5	-2.15	-0.704		5	-3.31	-1.305	
O	5	-0.88	-0.2[illegible]9		5	0.51	0.276	
P	5	1.17	0.304		5	2.86	1.715	
H to I	4	7.21	4.489		4	-2.42	-0.768	

Table 5e (Continued)

	J	2	10.92	6.991		2	-0.37	-0.106	
	L	4	7.8	1.912		4	-4.15	-1.162	
	M	2	1.95	0.385		2	2.23	0.597	
	N	4	9.55	5.647	0.005	4	0.48	0.140	
	O	4	10.82	3.474	0.025	4	4.3	1.450	
	P	4	12.87	4.462	0.01	4	6.65	2.327	0.05
I to	J	4	3.71	1.656		4	2.05	0.835	
	L	6	0.59	0.135		6	-1.73	-0.677	
	M	4	-5.26	-0.989		4	4.65	1.675	
	N	6	2.34	1.003		6	2.9	1.225	
	O	6	3.61	1.030		6	6.72	4.184	0.005
	P	6	5.66	1.714		6	9.07	6.495	0.0005
J to	L	4	-3.12	-0.714		4	-3.78	-1.271	
	M	2	-9.02	-1.700		2	2.6	0.821	
	N	4	-1.37	-0.595		4	0.85	0.302	
	O	4	-0.10	-0.029		4	4.67	2.112	
	P	4	1.95	0.594		4	7.02	3.401	0.025
L to	M	4	-5.85	-0.899		4	6.38	1.967	
	N	6	1.75	0.396		6	4.63	1.597	
	O	6	3.02	0.588		6	8.45	3.640	0.01
	P	6	5.07	1.015		6	10.8	4.950	
M to	N	4	7.6	1.422		4	-1.75	-1.565	
	O	4	8.87	1.491		4	2.07	0.808	
	P	4	10.92	1.872		4	4.42	1.814	
N to	O	6	1.27	0.358		6	3.82	1.809	
	P	6	3.32	0.993		6	6.17	3.153	0.01
O to	P	6	2.05	0.483		6	2.35	2.611	0.025

Table 5f Comparisons of the groups of stands by soil sodium
(using the t - test)

Groups compared	Surface d.F	Surface $\bar{X}_1-\bar{X}_2$	Surface t	Surface p	Average d.F	Average $\bar{X}_1-\bar{X}_2$	Average t	Average P
A to B	4	-0.58	-2.258	0.05	4	-.505	-4.123	0.01
C	3	-0.0767	-0.316		3	-.2026	-1.510	
D	6	-0.35	-1.362		6	-.355	-3.550	0.01
E	3	-0.08	-0.329		3	.155	1.550	
F	2	-0.12	-0.467		2	-.065	-0.650	
G	3	0.00	0.000		3	-.025	-0.122	
H	2	-0.12	-0.467		2	.025	0.250	
I	4	-0.23	-0.[illegible]9		4	-.115	-1.286	
J	2	-0.23	-0.999		2	-.115	-1.286	
L	4	-0.29	-1.215		4	-.205	-1.955	
M	2	-0.23	-0.999		2	-.045	-0.503	
N	4	-0.23	-0.924		4	-.165	-1.197	
O	4	-0.17	-0.712		4	-.145	-1.225	
P	4	-0.08	-0.[illegible]76		4	.115	1.212	
B to C	5	0.5033	3.651	0.01	5	.3024	2.319	0.05
D	8	0.23	1.426		8	.15	1.581	
E	5	0.50	3.627	0.01	5	.66	6.957	0.0005
F	4	0.46	2.853	0.025	4	.44	4.638	0.005
G	5	0.58	2.620	0.025	5	.48	2.371	0.05
H	4	0.46	2.853	0.025	4	.53	5.587	0.005
I	6	0.35	3.070	0.025	6	.39	4.661	0.005
J	4	0.35	3.070	0.025	4	.39	4.661	0.005
L	6	0.29	2.224	0.05	6	.30	3.000	0.025
M	4	0.35	3.070	0.025	4	.46	5.498	0.005
N	6	0.35	2.360	0.05	6	.37	2.534	0.025
O	6	0.41	3.145	0.01	6	.36	3.157	0.01
P	6	0.50	2.384	0.05	6	.62	6.932	0.0005
C to D	7	-0.2733	-1.983	0.05	7	-.1524	-1.391	
E	4	-0.0033	-0.030		4	.3576	3.264	0.025
F	3	-0.0433	-0.314		3	.1376	1.256	
G	4	0.0767	0.374		4	.1776	0.847	
H	3	-0.0433	-0.314		3	.2276	2.078	
I	5	-0.1533	-1.979		5	.0870	0.876	

Table 5f (Continued)

Groups compared		Surface d.F	Surface $\bar{X}_1-\bar{X}_2$	Surface t	Surface p	Average d.F	Average $\bar{X}_1-\bar{X}_2$	Average t	Average p
D to	J	3	-0.1533	-1.979		3	.0876	0.876	
	L	5	-.2133	-2.133	0.05	5	-.0024	-0.021	
	M	3	-.1533	-1.979		3	.1576	1.576	
	N	5	-.1533	-1.252		5	.0376	0.259	
	O	5	-.0933	-0.933		5	.0576	0.455	
	P	5	-.0033	-0.017		5	.3176	3.028	0.025
	E	7	.27	1.959		7	.51	8.064	0.0005
	F	6	.23	1.426		6	.29	4.585	0.005
	G	7	.35	1.581		7	.33	1.739	
	H	6	.23	1.426		6	.38	6.008	0.0005
	I	8	.12	1.052		8	.24	5.367	0.0005
	J	6	.12	1.052		6	.24	5.367	0.005
	L	8	.06	0.460		8	.15	2.121	0.05
	M	6	.12	1.052		6	.31	6.932	0.005
	N	8	.12	0.809		8	.19	1.666	
	O	8	.18	1.381		8	.21	2.348	0.025
	P	8	.27	1.287		8	.47	8.581	0.0005
E to	F	3	-0.04	-0.290		3	-.22	-3.479	0.025
	G	4	.08	0.390		4	-.18	-0.949	
	H	3	-.04	-0.290		3	-.13	-2.055	
	I	5	-.15	-1.936		5	-.27	-6.073	0.005
	J	3	-.15	-1.936		3	-.27	-6.073	0.005
	L	5	-.21	-2.100	0.05	5	-.36	-5.091	0.005
	M	3	-.15	-1.936		3	-.20	-4.472	0.025
	N	5	-.15	-1.225		5	-.32	-2.807	0.025
	O	5	.09	0.900		5	-.30	-3.354	0.025
	P	5	0.00	0.000		5	-.04	-0.730	
G to	H	3	-0.12	-0.542		3	.05	0.264	
	I	5	-.23	-1.212		5	-.09	-0.488	
	J	3	-.23	-1.212		3	-.09	-0.488	
	L	5	-.29	-1.450		5	-.18	-0.936	
	M	3	-.23	-1.212		3	-.02	-0.108	
	N	5	-.23	-1.084		5	-.14	-0.660	
	O	5	-.17	-0.850		5	-.12	-0.600	
	P		-.08	-0.309		5	-.14	-0.748	

Table 5f (Continued)

Groups compared	Surface d.F	Surface $\bar{X}_1-\bar{X}_2$	Surface t	Surface p	Average d.F	Average $\bar{X}_1-\bar{X}_2$	Average t	Average p
H to I	4	-.11	-0.965		4	-.14	-3.130	0.025
J	2	-.11	-0.965		2	-.14	-3.130	0.05
L	4	-.17	-1.304		4	-.23	-3.252	0.025
M	2	-.11	-0.965		2	-.07	-1.565	
N	4	-.11	-0.742		4	-.19	-1.666	
O	4	-.05	-0.333		4	-.17	-1.901	
P	4	-.04	0.191		4	.09	1.643	
I to I	4	0	0.000		4	0	0	
L	6	-.06	-0.949		6	-.09	-1.643	
M	4	.0	0.000		4	.07	00	0.0005
N	6	0	0.000		6	-.05	-0.477	
O	6	.06	0.949		6	-.03	-0.387	
P	6	.15	0.852		6	-.23	7.273	
J to L	4	-.06	-0.949		4	-.09	-1.643	
M	2	0	0.000		2	.07	00	
N	4	0	0.000		4	-.05	-0.477	
O	4	.06	0.949		4	.03	0.387	
P	4	.15	0.852		4	.23	7.273	
L to M	4	.06	0.949		4	.16	2.921	0.025
N	6	.06	0.526		6	.04	0.338	
O	6	.12	1.342		6	.06	0.632	
P	6	.21	1.122		6	.32	5.060	0.005
M to N	4	0	0.000		4	.12	-1.144	
O	4	.06	0.949		4	-.10	-1.291	
P	4	.15	0.852		4	.16	5.059	0.005
N to O	6	.06	0.526		6	.02	0.153	
P	6	.15	0.750		6	.28	2.556	0.025
O to P	6	.09	0.481		6	.26	3.508	0.01

Table 5g Comparisons of Groups of stands by Altitude (using the t-test)

Groups compared		d.F	$\bar{X}_1-\bar{X}_2$	t	p
A to	B	4	-92.5	16.5496	0.0005
	C	3	11.7	.1842	
	D	6	-246.67	3.8056	0.005
	E	3	-65.0	0.7241	
	F	2	25.0	0.2773	
	G	3	18.33	1.8077	
	H	2	-125.0	1.7813	
	I	4	-152.5	6.5157	0.005
	J	2	-120.0	16.9740	0.005
	L	4	35.0	2.3337	0.05
	M	2	--60.00	3.7953	0.05
	N	4	15.0	0.3906	
	O	4	-62.5	5.8388	0.005
	P	4	-37.5	1.7094	
B to	C	5	104.2	1.6439	
	D	8	-154.17	2.3840	0.025
	E	5	27.5	0.3067	
	F	4	117.5	1.3050	
	G	5	110.83	12.0868	0.0005
	H	4	-32.5	0.4640	
	I	6	-60.0	2.6085	0.025
	J	4	-27.5	4.9201	0.005
	L	6	127.5	8.8793	0.0005
	M	4	32.5	2.1375	0.05
	N	6	107.5	2.8169	0.025
	O	6	30.0	3.0644	0.025
	P	6	55.0	2.5574	0.025
C to	D	7	-258.37	2.8554	0.025
	E	4	-76.7	0.6989	
	F	3	13.3	0.1209	
	G	4	6.63	0.1037	
	H	3	-136.7	1.4481	
	I	5	-164.2	2.4335	0.05
	J	3	-131.7	2.0730	
	L	5	23.3	0.3590	
	M	3	-71.7	1.1016	
	N	5	3.3	0.0447	
	O	5	-74.2	1.1587	
	P	5	-49.2	0.7361	

Groups compared		d.F	$\bar{X}_1-\bar{X}_2$	t	p
D to	E	7	181.67	1.6441	
	F	6	271.67	2.4520	0.025
	G	7	265.00	4.0631	0.005
	H	6	121.67	1.2772	
	I	8	94.17	1.3738	
	J	6	126.67	1.9543	
	L	8	281.67	4.2580	0.005
	M	6	186.67	2.8139	0.025
	N	8	261.67	3.4886	0.005
	O	8	184.17	2.8199	0.025
	P	8	209.17	3.0733	0.01
E to	F	3	90.0	0.7086	
	G	4	83.33	0.9253	
	H	3	-60.0	0.5276	
	I	5	-87.5	0.9460	
	J	3	-55.0	0.6127	
	L	5	100.0	1.1021	
	M	3	5.0	0.0550	
	N	5	80.0	0.8215	
	O	5	2.5	0.0277	
	P	5	27.5	0.2985	
G to	H	3	-143.33	2.0316	
	I	5	-170.83	6.9704	0.0005
	J	3	-138.33	13.6420	0.0005
	L	5	16.67	1.0002	
	M	3	-78.33	4.5017	0.025
	N	5	-3.33	0.0852	
	O	5	-80.83	6.2470	0.005
	P	5	-55.83	2.4158	0.05
H to	I	4	-27.50	0.3735	
	J	2	5.0	0.0713	
	L	4	160.0	2.2406	0.05
	M	2	65.0	0.9080	
	N	4	140.0	1.7569	
	O	4	62.5	0.8848	
	P	4	87.5	1.1956	
I to	J	4	32.5	1.3886	
	L	6	187.5	6.9744	0.0005
	M	4	92.5	3.3827	0.01

Table 5g (Continued)

Groups copared		d.F	$\overline{X}_1-\overline{X}_2$	t	p
	N	6	167.5	3.7710	0.005
	O	6	90.0	3.6368	0.01
	P	6	115.0	3.6753	0.01
J to	L	4	155.0	10.3349	0.0005
	M	2	60.0	3.7953	0.05
	N	4	135.0	3.5150	0.025
	O	4	57.5	5.3717	0.005
	P	4	82.5	3.7607	0.01
L to	M	4	-95.0	4.6089	0.005
	N	6	-20.0	0.4924	
	O	6	-97.5	5.7300	0.005
	P	6	-72.5	2.8302	0.025
N to	N	4	75.0	1.8325	
	O	4	-2.5	0.1410	
	P	4	22.5	0.8621	
N to	O	6	-77.5	1.9751	
	P	6	-52.5	1.2024	
O to	P	6	25.0	1.0700	

Table 5H   Comparisons of the groups of Stands by slope (using the t-test)

Groups compared		Surface d.F	Surface $\bar{X}_1-\bar{X}_2$	Surface t	Surface p
A to	B	4	-3.0	0.6763	
	C	3	-1.5	0.3420	
	D	6	-0.83	0.2166	
	E	3	-0.5	0.1309	
	F	2	1.0	0.2324	
	G	3	-7.17	1.2235	
	H	2	-2.5	0.6871	
	I	4	-11.75	2.6971	0.05
	J	2	-7.5	1.4106	
	L	4	-9.5	2.0217	
	M	2	-3.0	0.4601	
	N	4	-7.25	1.9046	
	O	4	-3.5	0.9010	
	P	4	-6.25	1.4286	
B to	C	5	1.5	0.3950	
	D	8	2.17	0.6907	
	E	5	2.5	0.7998	
	F	4	4.0	1.0807	
	G	5	-4.17	0.7675	
	H	4	0.5	0.1723	
	I	6	-8.75	2.3253	0.05
	J	4	-4.5	0.9293	
	L	6	-6.5	1.5646	
	M	4	0	0.0000	
	N	6	-4.25	1.3667	
	O	6	-0.5	0.1560	
	P	6	-3.25	0.8583	
C to	D	7	0.67	0.2132	
	E	4	1.00	0.3274	
	F	3	2.5	0.6855	
	G	4	-5.67	1.0514	
	H	3	-1.00	0.3540	
	I	5	-10.25	2.7672	0.025
	J	3	-6.00	1.2508	
	L	5	-8.00	1.9506	
	[illegible]	[illegible]	[illegible]	[illegible]	
	N	5	-5.75	1.8926	
	O	5	-2.00	0.6379	
	P	5	-4.75	1.2750	
D to	E	7	0.33	0.1509	
	F	6	1.83	0.6201	
	G	7	-6.34	1.2801	
	H	6	-1.67	0.9017	
	I	8	-10.92	3.6061	0.005
	J	6	-6.67	1.5524	
	L	8	-8.87	2.5322	0.025
	M	6	-2.17	0.3795	
	N	8	-6.42	2.9676	0.01
	O	8	-2.67	1.1620	
	P	8	-5.42	1.7744	
E to	F	3	1.5	0.5112	
	G	4	-6.67	1.3495	
	H	3	2.00	1.0960	
	I	5	11.25	3.7355	0.01
	J	3	7.00	1.6337	
	L	5	9.00	2.5797	0.025
	M	3	2.5	0.4379	
	N	5	6.75	3.1541	0.025
	O	5	3.00	1.3131	
	P	5	-5.75	1.8926	
G to	H	3	4.67	0.9721	
	I	5	-4.58	0.8531	
	J	3	-0.33	0.0535	
	L	5	-2.33	0.4124	
	M	3	4.17	0.5763	
	N	5	-0.08	0.0162	
	O	5	3.67	0.7350	
	P	5	0.92	0.1709	
H to	I	4	-9.25	3.3291	0.025
	J	2	-5.00	1.2121	
	L	4	-7.00	2.1281	
	M	2	-0.5	0.0394	

Table 7 Plant Associations

Group & No. of Stands	Species by which the group is identified	Plants with high frequencies in the group
A(2)	+ Erica arborea, + Rhus glutinosa + Nuxia congesta	E. arborea, Juniperus procera N. congesta, Olea africana Olinia aequipetala and R. glutinosa
B(4)	+ E. arborea + R. glutinosa - N. congesta + Helichrysum cymosum	Carissa edulis, E. arborea, H. cymosum, J. procera Myrsine africana O. africana, Osyris arborea, and R. glutinosa
C(3)	+ E. arborea + R. glutinosa - N. congesta - H. cymosum.	E. arborea, J. procera, M. africana, D. africana and Pittosporum sp.
D(6)	+ E. arborea - R. glutinosa + Myrica salicifolia	E. arborea, Halleria lucida, Ilex mitis J. procera, M. salicifolia, Pittosporum sp., and Rappanea, melanophloears
E(3)	+ E. arborea - R. glutinosa - M. salicifolia	Bersama abyssinica, C. edulis, E. arborea, J. procera O. africana and O. aequipetala.
G(3)	- E. arborea - O. arborea + Kolfa (Mukeguracha)	Dovyalis verucosa, Eckebergia capensis Kolfa (Mukeguracha), M. africana Sideroxylon gileti
H(2)	-E. arborea - O. arborea - Kolfa (Mukeguracha) + R. glutinosa + Maesa lanceolata	H. lucida, J. procera, M. africana, Podocarpus gracilior, and R. glutinosa
I(4)	- E. arborea - O. arborea - Kolfa (Mukeguracha) +R glutinosa - M. lanceolata + Jasminium abyssinicum	Allophylus spp; Galiniera coffeoides, J. procera Lobelia giberoa, N. congesta, O. aequipetala, Pentas lanceolata, P. gracilior, and Pygeum africanum.

Table 7 cont'd

Group & No. of Stands	Species by which the group is identified	Plants with high frequencies in the group
J(2)	- E. arborea - O. arborea - Kolfa (Mukeguracha) + R. glutinosa - M. lanceolata - J. abyssinicum	Same as group I
L(4)	- E. arborea - O. arborea - Kolfa (Mukeguracha) - R. glutinosa + D. verucosa - Rubus apetalus + C. adulis	C. edulis, Dovyalis abyssinica D. verucosa E. capennis, E. obovali folia J. procera, O. aequipetala, and P. gracilior
M(2)	- E. arborea - O. arborea - Kolfa (Mukeguracha) - R. glutinosa + D. verucosa - R. apetalus - C. edulis + Senecio gigas	D. verucosa, E. capensis, J. procera L. giberoa, M. africana, O. africana and P. africanum
N(4)	- E. arborea - O. arborea - Kolfa (Mukeguracha) - R. glutinosa + D. verucosa - R. apetalus - C. edulis - S. gigas + Bersama abyssinica	D. verucosa, E. capensis G. coffeoides, H. lucida, J. procera O. africana, O. aequipetala, P. africanum P. gracilior and R. simenses
O(4)	- E. arborea - O. arborea -Kolfa (Mukeguracha) - R. glutinosa + D. verucosa - R. apetalus - C. edulis - S. gigas - B. abyssinica	D. verucosa E. capensis, G. coffeoides, J. procera, M. africana, O. africana P. africanum, Teclea nobilis.
P(4)	- E. arborea - O. arborea - Kolfa (Mukeguracha) - R. glutinosa - D. verucosa	E. capensis, G. coffoides, N. congesta, O. africana, O. aequipetala, P. lanceolata, P. africnum and R. simensis.

CHAPTER 4

SOME RECOMENDATIONS ON THE MANAGEMENT OF THE MANAGESHA STATE FOREST

The Menagesha State Forest could be viewed as having two more or less distinct vegetation categories. The first category which is identified by the presence of *E. arborea* has low conductivity, pH and cations in the soil. The soils in this category are deeper which shows that they are more developed and older soils which are leached resulting in low nutrient status. In addition as can be seen from the raw data, there are many more broad leaved species and in higher densities in the -*Erica* category than in the + *Erica* category. The effect of leaching is, therefore, presumably more intense in the + *Erica* category. The - *Erica* category have soils that are on the average shallower. The group of stands occur on steeper slopes, thus leaching would be expected. However, conductivity, pH, and cations are higher. This arises presumably from the increased rate of nutrient cycling implied by the increased biomass of deciduous species.

Since the Menagesha State Forest is one of the few remaining forests in Central Ethiopia, and so far the best protected, it should continue to be conserved. This does not mean that it should never be exploited. Conservation implies the wise use of natural resources for better exploitation, i.e. for better economic development (Dasmann et al 1973). If there is any need to remove trees for timber, they should be taken only from category 2. Even from category 2 trees should not be removed indiscriminately. Removal of the vegetation indiscriminately would result in the disruption of the nutrient cycle and a marked fall in the productivity of the area.

From observations in the Menagesha State Forest it was found that areas in the lower limits of the forest are under Pinus species plantations. However, studies made in East Africa (Tanzania), (Robinson, et al 1966; Lundgran 1978) have shown that there is a decrease in nutrient status of the soil of man made forests under Pinus patula and Cupressus lusitanica when compared with natural forests. Robinson et al studied the differences between the soils of a 16 year old Cuppressus lusitamica and an idiginous montane forest and found that under C. lusitanica a significant decrease occurred in the top soil organic carbon, nitrogen and mineral nutrient and content and a decrease in pH. Lundgren in his study of the soil conditions and nutrient cycling under monoculture plantations of C. lusitapics and P. patula biomass when compared with the nutrient content in the plant biomass in a natural forest. In addition, replacement of the original natural vegetation by new exotic species has a drawback like any other monoculture, i.e. it will be succeptible to an increasing number and variety of diseases, parasites, and insects or other animal pests (Dasmann, et al, 1973).

Plantations of either exotic or native species is permissable on eroded and devastated soils. This is probably the only method of restoring the natural conditions. Thus planting new plant species in category 1 may bring better soil conditions and consequently better plant growth. In the nutrient poor areas of the Menagesha State Forest then, if shrubs including kolfa (Mukaguracha) that have low nutrient requirement are planted, they will adapt better and may bring better conditions for subsequent plantation by other species of higher nutrient requirements, e.g. *M. lanceolata* followed by *C. edulis*. The nutrient status of the soil, would then be expected to improve, since, as discussed above, the indication is that the last two species increase nutrients in the soil. Once the soil is established the economically useful trees (timbers) could be grown. But trying to grow conifers, which are the commonly used species for reafforestation in such nutrient poor areas may increase rates of nutrient loss rather than improve site conditions.

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