AN ECOLOGICAL STUDY
OF THE MONTANE GRASSLAND VEGETATION
IN WOLMERA WOREDA

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ABSTRACT

A study of the grasslands in Wolmera Wereda was made from A August 1979 to October 1979. One hundred and twenty stands were systematically sampled and the occurence of 118 plant species in the stands recorded. Some environmental factors were recorded and soil samples collected.

Computations of the classification of the vegetation using the Association Analysis Technique was made at the University of Manchester Regional Computer Center.

Four distinct vegetation types were tentatively identified from the dendrogram at higher levels of the classificatory hierarchy and were statistically tested for significant contrasts.

Gradients of soil pH, conductivity, hue, and cation content are positively correlated with a decreasing drainage gradient and these are negatively correlated with an increasing grazing gradient.

1. INTRODUCTION

Ecology, montane and grassland are terms which may require definition and brief descriptions of the ways in which the terms are used here are given below.

Ecology in brief is the study of the interrelationships of organisms with their environments. Montane is related to, or being the biogeographical region made up of relatively moist, cool upland slopes below timber line and characterized by the presence of large evergreen trees as dominant life forms. (The new Encyclopedia Britanica,1976). Included in the Montane grasslands are communities of grasses about 1 m. height at altitudes roughly between 1,800 m. and 2,500 m. and communities of much shorter grasses at altitudes mostly above 2,500 m. (Keay, 1959).

Grassland in its broadest sense is, of course, commonly used to describe one of the main vegetation formations on the Earth's surface, as opposed to forest and desert. In this sense it includes all those types of vegetation characterized by the presence of both woody plants grasses and herbs but where the biomass production is highest in the herbaceous component of the vegetation.

From the ecological point of view grasslands develop as direct expression of the climate or as a result of a certain set of conditions both of which are unfavorable to the growth of trees. A secondary or derived grassland may also develop as a result of biotic influences (McIllory, 1962).

It is a matter of common observation that plants occur in a number of easily recognisable communities eg. on hill sides, or lower slopes and on stream banks. All such natural communities are established by a process of gradual development and for each community this follows a characteristic pattern in which a series of definite stages can be recognized. This process of development of plants communities is known as plant succession (Clements cited in Odum, 1971).

The rate at which the changes take place and the actual species of plant found depend naturally up on a large number of factors and differ from place to place.

It may not be possible here to consider all combinations of factors that affect the rate of succession. In general, however, the development of the great majority of plant communities commencing on bare ground follows a similar pattern. If the succession begins on an area that has never had plants growing on it, it is termed a primary succession. If it is the result of some modification or destruction it is termed a secondary succession.

The effect of human activities can be catagorized under two main points. The first includes the effect arising from activities like plowing , that remove the existing vegetation and leave bare areas for reinvasion by plants. The second includes activities such as draining swamps, grazing and grass burning, which cause gradual modification of the vegetation (Bayer, 1959).

By clearing the woody vegetation, a good growth of grass may be made to appear which may persist for a number of years before the woodland takes over again. In many parts of Africa including parts of Ethiopia these grasslands have been maintained by fires, often man made (Rattray, 1960).

Predation is necessary for the maintenance of stable ecosystems. Without it the carrying capacity of the environment will be reached by the prey component, the result of which is intense competition or population crush - Lighten any check, mitigate the destruction even so little, and the number of species will almost instantaneously increase to any amount (Darwin cited in Dajoz, 1975). There is an optimum predation which the prey population can tolerate. (Odum, 1971). Grazing is no different from this.

Grazing and trampling of the same area continuously every year by large concentrations of game or domestic livestock will result in degradation of the grass cover and extensive areas could be taken over by vegetation less desirable for grazing and often low in succession (Rattray, 1960).

Understocking too can bring about changes in the grass cover, often of a retrogressive nature, as selective grazing is encouraged and palatable species may eventually be eliminated with corresponding increase in less palatable types. A feature of undergrazing which reduces grass productivity is that much of the dead biomass is left at the end of the growing season and carried over into the next and this chokes new growth (McIllory, 1972).

It is, however, not only overstocking or understocking that can bring about change in the composition. An undisturbed grass cover will also deteriorate in a few years time if it is not grazed or burned periodically. The accumulation of old grass and other plant materialy often becomes so dense that many plants are choked out and patches of bare ground result and these eventually will become covered with annual weeds and the grass cover will be altered both in composition and density (Rattray, 1960).

The ecological factors associated with occurence of natural grasslands have been the subject of much dispute and it appears that the relative importance of different factors vary in different regions and in different types of grassland. While climatic factors are undoubtly of some importance, they appear to be of significance mainly in determining the limits within which grasslands may occur when other factors are favorable (Bayer, 1959).

In this study analyses of the response of vegetation to various presumed biotic and abiotic variables are made to provide an insight into the structural and functional variability among the communities. The technique employed to summarize the information and make them amenable to interpretation is association analysis.

The wet and dry evergreen montane forest which used to cover a large part of the Ethiopian plateau has now dwindled away. Only four percent of the relic forest is remaining as patches in inaccessable areas (Brown, 1973; Eckholm, 1976).

This makes the study of grasslands in Ethiopia important in at least two respects (a) Ethiopia is an agricultural country and cattle rearing is an important part of the mixed agriculture which is prevalent, and (b) the grasslands cover a large proportion of the country which provide natural pastures for grazing animals, a principal source of food.

2. LITERATURE REVIEW

The two well known theories concerning the nature of vegetation are the community concept (community unit theory) and the continuum concept (species individuality and community continuity theory).

A detailed review of these theories has been given by McIntosh (1967). Here it should first be remarked that probably few ecologists now hold either theory in its pure form. In fact a technique employed to elucidate the one is taken as an alternative or an adjunct to the other (Whittaker 1967; Grunow 1967; Pielou 1969 and Anderson 1971).

These techniques are necessary because the amount of data is such that patterns of association cannot easily be detected and the information should be summarized whilst retaining most of the interunit relationship. Vegetation is a complex matrix which for simplicity can be viewed as two dimensional (n X m), m stands and n species. The summary of the information can be accomplished by compressing the m X n matrix table of the data (n rows and m columns) horizontally (gradient analysis or ordination) or vertically (cluster analysis or classification) (Patrichard and Anderson, 1971).

Both theories involve methods of structuring in that both are aimed at seeking a simpler structure than that of the original raw data (Lambert and Dale, 1964). In either case the primary aim is to simplify a complex situation by reduction in the number of axes or classes to be assessed; and in either case the degree of simplification eventually adopted depends on the criteria imposed by the user and not on the method itself (Greig Smith, 1964 and Lambert & Dale, 1964). There is no a priori reason why vegetation structure should be such that either classification or ordination can be accepted as an inherently correct technique for the reduction of natural complexity to a comprehensible order (Anderson, 1964).

2.1 Gradient Analysis (Ordination)

In early vegetation studies, it was generally taken for granted that the vegetation consisted of the community types into which it was classified. The community types were assumed to be well defined natural units which were part of the structure of the vegetation and which generally joined each other along narrow boundaries called ecotones.

This theory which did not have a particular name was later designated as community unit theory (Whittaker, 1962).

According to Whittaker (1956) the dissent from this theory was first effectively stated in America by Gleason in 1926. Much of the same idea had been expressed in Russia by Ramensky in 1924. Ramensky is thus recognized as the originator of gradient analysis.

For two decades the dissent of Gleason and Ramensky remained latent until in the summer of 1947 a study was carried out in the Great Smoky Mountains of Tennessee by Whittaker (1956), which supported Ramensky's ideas. Vegetation had then been concieved of as primarily a complex continuum of populations, rather than a mosaic of discontinuous units. The method of research which dealt with vegetation interms of continuity and gradient relationships was termed gradient analysis.

The gradient analysis of Whittaker is to take some well marked gradient - e.g. altitude in the Great Smoky Mountains (Whittaker, 1956) and to assign scores to the species according to their altitudinal preference. Sites are then ordinated by taking the average of scores of the species which occur in them. This technique has been reviewed in detail by Whittaker (1967).

With gradient analysis as a method, two approaches may be distingushed - direct analysis in relation to an environmental gradient accepted as given and an indirect analysis in which axes of variation are obtained from similarity measurements between stands (sampling units).

In the direct analysis, an environmental gradient may be accepted as given and its values, arranged in an ascending or descending order, are used to order the stands (Whittaker, 1967).

The indirect gradient analysis (Ordination proper) has also been reviewed by Whittaker (1967), Orloci (1966), Anderson (1971), McIntosh (1967) and Gauch and Whittaker (1972) etc.

An ordination is an arrangement of communities, species or environments in sequence which is hoped to reveal maximum information about the relationships among them and which will also reveal such classes as may exist (McIntosh, 1967).

The indirect gradient analysis variously called ranking or multidimensional scaling in other sciences (Anderson, 1971), has ranged from the crude procedures of Bray and Curtis (Orloci, 1966) to the recent and mathematically complex ordination techniques eg. principal components analysis, which necessarily involve the extensive use of electronic computers.

Although it requires some improvements (Orloci, 1974), Gauch & Whittaker (1972) have recommended the Bray and Curtis ordination as the more lucid and computionally enormously simpler (but unwiedly for large samples (Kershaw, 1973) research tool over the mathematically objective, but illusory principal components analysis. Austin & Greig-Smith (1968) and Beals (1973) have also emphasized the need for a detailed assessment of these techniques and particularily a reappraisal of the earlier methods. Whittaker (1967), in his comprehensive review of ordination methods, maintains that the mathematically simpler methods give better results.

The Bray and Curtis technique uses the coefficient of similarity, $C = 2W/(a + b)$, where a and b are quantities of all plants found in the two stands to be compared and W is the sum of the lesser value of those species common to the two stands.

When vegetation samples are ordinated, the problem is one of associating the ordination axis with the environmental variables. This is the object of Whittaker's gradient analysis, (Whittaker, 1967).

According to Austin & Noy-Meir (1971) direct interpretation of ordination axes in terms of environmental gradients is rarely possible even in an ideal continuum, because ordination is a linear mapping technique, while vegetation / environment relationships are non-linear.

Whittaker's gradient analysis was recently refined and designated as indicator species analysis (Hill et al. 1975) and Reciprocal averaging (Hill, 1973). The refinements of Hill and Hill et al. combine the gradient analysis of Whittaker with a scheme of successive approximations.

From rough floristic data, eg. a gradient in grazing conditions, the species are divided into two, namely those occurring in grazed areas and those in ungrazed areas. By assigning "0" to each of the species presumed to be in one group and "100" to the other group, an initial gradient analysis is obtained.

Simple matrix algebra will give a one dimensional ordination of both the species and the stands after repeated cross calibration, until the scores stabilize. This process is called reciprocal averaging. By the use of reciprocal averaging a stand ordination is reached very similar to what would be obtained from principal components analysis (Hill, 1973). Reciprocal averaging is used in preference to principal components analysis, because it is computationally simpler and easier for interpretation. It also generates good simultaneous species ordinations and the method works satisfactorilly well for presence and absence data (Hill, 1973).

TWINSPAN - A FORTRAN program written by Hill (1979) is a very recent improvement upon the original indicator species analysis.

2.2 Cluster Analysis (classification)

Cluster analysis or classification which originated from considerations of the community unit theory, seeks to divide the stands (and by inference the region surveyed) into groups of high internal similarity with respect to their species.

The history of the schools of Ecology and techniques aimed at identifying the community units implied in the community unit theory have been reviewed by Whittaker (1962). Many techniques have been developed since then. These have been summarized by Williams and Dale (1965) and Tewolde (1969).

The different classificatory techniques can be characterized as:- hierarchical or reticulate, divisive or agglomerative, and monothetic or polythetic.

In hierarchical classification the classes at any level are subclasses of classes at a higher level. In a reticulate classification the clusters are defined separately and the links between them have the form a network rather than a tree.

In a divisive classification we begin with a whole collection of stands and divide it and keep re-dividing the subdivisions to arrive at ultimate classes. In an agglomerative classification we start at the bottom and work upwards, beginning with the individual stands combining them to form successively more inclusive groups of stands.

In monothetic classification two "sister" groups are distingushed by the fact that one has and the other lacks a single attribute. In polythetic classification two groups are combined or separated on the basis of their over all similarities, similarity being defined so as to depend on a number of attributes.

Hierarchical techniques are preferred to reticulate techniques for the reasons given by Williams and Lambert (1960), namely that they are better known, less cumbersome and more widely used in ecological works.

Divisive techniques also have two great advantages over agglomerative techniques. (a) The computations are generally much simpler, since we do not usually need the division down to the point at which individual stands are recognized as classes.
(b) In agglomerative techniques the recombination is begun with the smallest units (the stands themselves) and since these are the ones where chance anomalies are most likely to obscure the true affinities the result of combination is likely to be bad; But in divisive techniques chance anomalies have a higher chance of being masked.

Although a monothetic technique is wasteful of information and can lead to a meaningless subdivision, divisive monothetic methods are feaseble for ecological works, divisive polythetic methods are not because they are computationally more complex (Pielou, 1969).

A technique that combines the preferred techniques namely hierarchical, divisive and monothetic is association analysis (Williams and Lambert, 1959, 1960; and Lambert and Williams, 1962).

The argument underlying the techniques is as follows:- If any pair of species in the vegetation exhibits an association, either positive or negative, the vegetation must be hetergoenous and hence amenable to classification. The stands are to be classified by dividing them into groups within which inter-species association is non existent or minimal. Then each group can be regarded as homogenous. To do this we first divide the whole set of stands on the species that shows the greatest degree of association with other species. This species has been called by Pielou (1969) a critical species. The first division of the stands is into those containing the critical species and those lacking it.

Each of the groups is now treated as a new set and the process is repeated until groups are untimately reached in which there is no significant association.

In association analysis the method of choosing the critical species is to calculate an index of association "I" between every pair pair of species. Thus if there are n species the matrix of indeces will be n X n with the diagonal of 0 values. The matrix, is in fact, symmetrical and only $\frac{n(n-1)}{2}$ values of the index need to be calculated. The elements in the matrix are then summed up by columns or rows and the critical species is that having the greatest values of the sum of I. The three indices used by Williams and

Lambert as possible measures of association are chi square, chi square corrected for continuity and the square root of chi square divided by the total number of stands. These inices are defined as follows. The occurrence of the two species for which the index is being calculated is entered in the following 2 X 2 contingency table the cells of which are named A, B, C and D in which:-

Species X

Species Y		+	–	
	+	A	B	A + B
	–	C	D	C + D
		A + C	B + D	m

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

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

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

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

Then chi square = $\dfrac{(AD - BC)^2 \cdot m}{(A + B)(C + D)(A + C)(B + D)}$

chi square corrected $\dfrac{(AD - BC - \frac{n}{2})^2 \, m}{(A + B)(C + D)(A + C)(B + D)}$

and $X^{1/2}/m = \dfrac{\left[\dfrac{(AD - BC)^2 \, m}{(A + B)(C + D)(A + C)(B + D)}\right]^{1/2}}{m}$

As indicated association analysis is successfully achieved by qualitative (subjective) data such as presence and absence. But Kershaw in 1961 used a covariance matrix instead of association matrix for data having a measure of the amount of each of species in the stands. He has also criticized the use of X^2 as a measure of a association because the stand size affects the index of association and still maintanins his criticism (Kershaw, 1973).

It has, therefore, been decided that Association Analysis, which has many preferable qualities over the other alternatives be employed in this work.

3. THE STUDY AREA

The data come from diverse communities, all broadly classified as grasslands in Wolmera district, Shoa, Ethiopia. The district is located about 30 km. west of Addis Ababa (8^{o} 50' - 9^{o} 14'N and 38^{o} 26' - 38^{o} 40'E in the northern part and 38^{o} 22.5' - 38^{o} 30'E in the southern part).

The district has an area 42,000 hectares (420 sq. km). The sites sampled are located on a variety of land forms. Most of the sites are on a level to undulating terrain, and some are characterized by gentle to steep slopes. The altitude of the sites range between 2,000 to 2,600 m. above sea level.

The sites are either fields which have been fallowed or mesic grasslands managed and regularily mowed or marshy areas wet for most part of the year and left for grazing. Some of the mesic grasslands are also under permanent grazing.

The population of the district is 78,000 (Ethiopian Science and Technology Commission, 1979). Most of the district is under cultivation growing cereals, pulses and vegetables or permanently under perennial crops including _Musa ensete_, _Eucalyptus globulus_, _Rhamnus prinoides_, etc. and or protected by hedges making uniform sampling of the region for grasslands impracticable.

One environmentally distinct area is called Bedi, in the northern part of Wolmera district where the farmers cultivate one variety of barley only (Balemy) after which the land is fallowed for one to several years until it regains its fertility (Zemedie 1980).

4. DATA COLLECTION AND TREATMENT

4.1 Data Collection

Seventeen sites scattered over the district were visited and sampled. The sampling commenced on August 19, 1979 and was completed on October 30, 1979.

At each site an apparently uniform area was chosen and a number of stands 3m X 3m, varying from 5 to 8 in number, were delimited. The plant species found in each stand were then recorded. Altogether 118 plants in 120 stands were recorded. When the identity of a plant was not certain, a specimen was collected for identification in the Herbarium. At the same time certain basic data were obtained from the stands. These data consisted of soil samples augered with a cover from the surface to 70 cm depth at 10 cm intervals, unless this became impossible because of encounter with a hard rock or unless it became too marshy for augering. Slope and aspect were determined sp. with a Brunton compass and altitude with an "Everest" altimeter made by Thommen of Switzerland. Grazing was recorded as "intensively grazed" when tusocks of *Pennisetum schimperi* became distinct and the rest of the vegetation was nibled close to ground level, moderately grazed when the grazing condition was slightly better, ungrazed and managed when the grassland was fenced and mowed at the appropriate season, ungrazed and unmanaged when the marshy condition discouraged grazing cattle and interference was minimal. Drainage condition were also recorded as marshy, temporarily wet during the rainy season or freely drained.

Soil samples collected in polyethylene bags were brought to the laboratory and air dried. Some chemical and physical properties of the samples were then determined.

The pH and electrical conductivity of the soil samples were determined using a portable Beckman Chem. Mate pH meter and a philip Harris conductivity bridge from a 1:1 soil-water mixture (30 gms of soil in 30 ml of water) prepared from samples at 20 cm intervals starting from the surface.

The dry and wet colors of the soil samples were compared with the 1959 edition of the Munsell soil color chart.

For the determination of the cations 5 gms of each soil sample from the surface and from 30-40 cm depth were weighed out and leached with 1 normal ammonium acetate solution. The sodium and potassium of each lechate were determined using a flame photometer made by Evans Electroselenium Ltd. at the central Laboratory and research Institute of the Ministry of Public Health.

4.2 Statistical Treatment of the Data

Vegetation Data

Association analysis of the data was run at the university of Manchester Regional Computer Center, England.

The program for the analysis was one that does not generate the highest single chi square at the subdivisions. The program was based on Williams and Lambert's long division i.e. division that keeps on going until a single stand is obtained unless computer core space is limiting. The alternative technique stops the subdivision when the highest single chi square is less than 3.841 (P = 0.05). The index used is $\underline{X}^2$. The plants under 5% occurrence in the stands sampled were not eliminated from the matrix. This resulted in many splinter groups.

Table 1. List of Plants Recorded in the Stands Sampled.

	Botanical name or Field name	Collection No.
1.	Alchemilla gracilipes (Engl)	1
2.	Andropogon chrysostachys Steudel	18
3.	Andropogon pratensis Hochst ex Haekel	128b
4.	Anthemis tigreensis J. Gay ex Richard	27
5.	Anthericum angustifolium Hochst ex Richard	9
6.	Aristida adscensionsis L.	110
7.	Arthroxon lacifolius (Trin.) Hochst	111
8.	Astragalus sp.	80
9.	Bidens pilosa L.	n.c.
10.	Acantheceae*	125
11.	Brachiara sp.	113
12.	Bunaw**	21
13.	Caucalis melanantha (Hochst.) B & H ex Hiern	3
14.	Centela asiatica (L.) Urban Mart.	127
15.	Kyllinga sp.	16
16.	Cyperus longus L.	26
17.	Cyperus sp.	99
18.	Scleria hispidior (C.B. Clarke) Nelmes	98
19.	Cerastium octandrum Hochst ex Rich	88
20.	Crepis carbonaria Schtz-Bip	5
21.	Commelina africana L.	52
22.	Commelina sp.	112
23.	Conyza aegyptica (L.) Dryand	19

Table 1. (Cont'd)

	Botanical name or Field name	Collection No.
24.	Corrigiola letoralis L.	62
25.	Craterostigma plantageum Hochstetter	38
26.	Crotalaria laburnifolia L.	63
27.	Cyanotis barbata Don	4
28.	Cynoglosum coeruleum Steud. ex Dc.	25
29.	Cynodon dactylon (L.) Richard	n.c.
30.	Dichrocephala integrifolia (L. Fil.) O. Kuntze	n.c.
31.	Digitaria velutina (Forsk.) Pal. Beauv.	23
32.	Helichrysum sp. 1	72
33.	Carduus chamaecephalus (Vatke) Oliv. & Hiern	17
34.	Eragrostis aethiopica Chiovenda	115
35.	Poa schimperiana Hochst. ex Richard	81, 68
36.	Eragrostis botroydes	51
37.	Eragrostis schweinfurthii Chiovenda	12
38.	Poa leptoclada Hochst. ex Richard	71
39.	Elusine floccifolia (Forsk.) Sprengel	30
40.	Eriosema longepedunculatum Rich	95
41.	Ethulia sp.	65
42.	Euphorbia petitiana Rich	n.c.
43.	Exotheca abyssinica (Hochst. ex Rich) Anderson	43
44.	Festuca abyssinica Hochst. ex Richard	22, 79
45.	Falkia oblonga Bernh	n.c.
46.	Galium spurium L.	n.c.

Table 1 (Cont'd)

	Botanical Name or Field name	Collection No.
47.	Geranium aculeolatum Oliv.	67b
48.	Guzotia scabra (Vis.) Chiovenda	n.c.
49.	Habenaria sp. 1	47
50.	Habenaria sp. 2	48
51.	Haphlocarpa ? hastata Lewin	122
52.	Helichrysum sp. 2	82, 7, 93
53.	Hyparrhenia arhenobasis (Hochst. ex. Steud.) Stapf.	104
54.	Hyparrhenia flipendula (Hochst) Stapf	126
55.	Hyparrhenia tubericulata Clayon	83, 45
56.	Hypericum pedlifolium Richard	57
57.	Inula glomerata Oliver & Hiern	74
58.	Impatiens Rothii Hook F.	n.c.
59.	Kniphofia isoetifolia Hochstetter	118
60.	Kyllinga appendiculata	15
61.	Laggera tomentosa Schtz. Bip. ex. Hochst.	34
62.	Lantana trifolium L	n.c.
63.	Labiateae*	63b
64.	Linaceae*	117
65.	Lotus Goetzei Harms	67a
66.	Medicago polymorpha	33
67.	Oenanthe palustris (Chiov.) Norman	32, 123
68.	Orobanche sp.	n.c.
69.	Oxalis corniculata L.	61
70.	Oxalis obliquifolia Steud. ex Rich.	2

Table 1. (Cont'd)

	Botanical name or Field name	Collection No.
71.	Oldenlandia monanthos (H. ex Rich.) Hiern	10
72.	Panicum repentallum Napper	109
73.	Panicum pussillum Hooker Fil.	102
74.	Paspalum orbiculare	107
75.	Pennisetum clandestinum Hochstetter ex. Chiovenda	29
76.	Pennisetum glabrum Hochst. ex. Steudel	70
77.	Pennisetum schimperi Richard	13
78.	Pennisetum villosum (R. Brown) Fresenius	39
79.	Plantago lanceolata L.	n.c.
80.	Plectocephalus varians (Rich) C. Jeffrey	n.c.
81.	Pimpinella sp.	35, 47b
82.	Plectranthus sp.	n.c.
83.	Poa annua L.	11, 24
84.	Polygala abyssinica	116
85.	Polygonum napalense Meissn.	60
86.	Rumex abyssinicus Jacq.	n.c.
87.	Rumex Bequaertii De Wild.	n.c.
88.	Rannunculus sceleratus L.	121
89.	Satureja abyssinica (Rich.) Briquet.	77
90.	Salvia nilotica Juss. ex Jacquin.	66
91.	Scleria clathrata Hochst. ex. Richard.	114
92.	Sedge**	120
93.	Silene Burchellii Ott.	91
94.	Sida cunefolia Roxb.	n.c.

Table.1. (Cont'd)

	Botanical name or Field name	Collection No.
95.	Sonchus sp.	54
96.	Spilanthus mauritiana (Rich ex Pers) Dc.	36
97.	Sporobulus africanus (Poir.) Robyns & Tourn.	14
98.	Senecio vulgaris L.	75
99.	Snowdenia polystachya (Fresen.) Pilger	n.c.
100.	Asteraceae	28
101.	Stephania abyssinica (Qu. Dill & Rich) Walpers	58
102.	Thesium sp.	20
103.	Scirpus setaceus L.	56
104.	Trifolium cryptopodium Steud. ex Rich.	49, 55, 84, 97
105.	Trifolium multinerve (Hochst.) Rich.	85, 105, 106, 117
106.	Trifolium simense Fresen	6, 41, 92, 124
107.	Trifolium semipilosum Fresen	7
108.	Trifolium schimperi (Hochst.) Rich.	53, 108
109.	Trifolium subrotundum	103
110.	Trifolium tembenses Fresen.	64, 86
111.	Trifolium sp.	128a
112.	Trifolium usambarense Taub. ap. Engler.	89
113.	Thymus serrulatus Hochst ex Benth	77
114.	Verbenaa officinalis L.	n.c.
115.	Veronica abyssinica Fresenius.	8
116.	Vicia sativa L.	128
117.	Vigna sp.	73

Table 1. (Cont'd)

	Botanical Name or Field name	Collection No.
118.	Ubelinia abyssinica Hochst.	31

n.c. = not collected

* = Family name only, pending determination.

** = Field name or code, pending determination.

Table 2. Summary Data of the Vegetation from Wolmera.

Stands and Plant Species Present in Them.

Stand No.	Plant Species
1	1,6,13,15,20,21,27,37,60,70,71,77,83,97,106,115.
2	1,2,13,15,20,27,33,37,49,50,70,71,77,97,107,115.
3	1,2,15,20,27,37,49,71,77,107,115.
4	1,2,12,13,15,20,23,27,37,49,71,77,97,102,106.
5	1,2,13,15,20,23,27,33,37,49,70,71,77,97,102.
6	4,9,13,23,27,28,31,37,44,83,100.
7	9,27,28,31,37,44,75,86,89,115.
8	13,15,20,31,37,44,71,75,83,89,110.
9	15,20,27,30,39,61,66,79,83,97,100,118.
10	23,30,31,33,66,79,96,106..
11	20,25,29,31,49,79,83,118.
12	2,6,15,20,27,31,37,66,78,83,94,97,107,118.
13	15,27,29,31,39,66,79,83,86,97,107.
14	1,3,9,16,18,27,36,39,41,48,53,77,81,106,109,118.
15	1,3,27,31,39,41,48,60,77,81,87,10,107,118.
16	1,3,9,18,21,27,36,50,53,97,102,106,107,118.
17	1,3,16,18,20,21,27,33,36,50,53,97,106,118.
18	1,3,15,16,18,21,27,50,53,73,76,77,97,102,106,110,118.
19	13,15,29,31,33,36,77,79,83,97,107,118.
20	27,29,31,33,39,77,79,81,83,97,100,118.
21	15,16,27,31,36,37,39,77,81,96,97,110,11,118.
22	27,29,31,33,36,37,39,77,83,97,111,118.

Table 2 (Cont'd)

Stand No.	Plant Species
23	15,20,27,31,33,36,75,77,81,83,97,110,111,118.
24	1,15,20,21,31,36,77,80,83,15,104.
25	1,3,21,27,36,53,77,95,97,103,106,110,118.
26	1,20,21,27,31,36,39,71,77,83,94, 107,110,115.
27	1,13,15,20,27,31,36,71,77,83,89,94,106,107,115, 118.
28	1,12,15,20,27,31,36,37,71,77,83,100,103,107,111,
29	1,15,20,27,31,36,71,77,83,89,97,103,107,
30	1,9,20,27,31,36,37,56,79,83,86,87,89,98,101,106,115.
31	1,20,27,29,30,31,36,46,48,56,79,83,86,87,98,104,106,110,115.
32	13,20,24,29,31,37,56,70,75,81,85,100.
33	9,13,20,24,26,29,30,31,33,37,70,79,81,86,89,96,100,115.
34	13,20,21,26,27,33,49,53,71,77,86,89,97,110.
35	1,9,20,29,36,37,39,77,81,83,85,86,96,97,104,110,111.
36	1,13,15,21,27,31,37,39,41,70,77,81,82,83,85,86,94,96,97,107, 110,111.
37	4,13,15,21,27,29,31,33,36,37,83,85,86,90,97,110,111,118.
38	1,13,20,27,31,37,39,41,46,70,75,81,83,86,90,97,107,110,111,118.
39	29,31,37,39,83,86,97,110,111,118.
40	1,13,15,20,27,29,31,33,37,41,66,77,79,81,83,85,86,97,106,107, 110,118.
41	13,20,21,27,31,36,77,79,81,83,86,97,106,111,118.
42	1,3,4,20,21,33,45,53,60,71,77,79,95,97,107,110,118.
43	1,3,20,21,27,36,45,53,60,71,77,96,97,102,104,107,118.
44	--

Table 2. (Cont'd)

Stand No.	Plant Species
45	1,3,20,21,27,36,37,45,53,60,77,79,94,97,107.
46	1,2,3,16,21,27,29,36,44,45,60,65,107,108.
47	1,15,20,21,27,29,31,33,36,39,77,79,83,97,101,107,118.
47B	1,3,21,27,29,36,45,53,60,65,77,79,83,94,95,97,103,107,108,118.
48	1,21,27,29,31,33,36,39,71,77,83,94,95,97,105,107,110.
49	1,3,15,16,19,21,27,39,44,54,76,83,87,101,104,105,118.
50	1,3,15,18,21,27,35,39,44,54,60,76,87,97,104,110,118.
51	1,3,16,17,19,27,35,39,44,54,60,76,79,87,104,107,110,118.
52	1,3,9,15,16,18,21,27,31,35,38,50,54,76,81,95,96,101,110.
53	1,3,9,15,16,18,21,36,54,97,110.
53B	3,9,16,19,21,27,37,39,54,76,81,110,118.
54	1,13,23,27,28,32,28,47,52,57,70,89,113,115,117.
55	1,2,13,21,27,32,38,46,47,57,77,86,89,90,106,109,113,117.
56	1,8,13,21,23,33,38,44,46,57,77,86,89,90,113,117.
57	1,9,13,23,28,29,31,32,38,44,46,47,76,77,89,105,106,107,117.
58	1,2,13,20,23,27,32,38,44,46,50,52,78,86,89,118.
59	1,13,21,32,33,37,38,47,52,55,77,81,89,97,106,118.
60	1,2,13,19,20,27,39,44,77,78,97,104,105,108,110,118.
61	1,3,9,13,19,20,27,31,34,35,36,38,44,71,77,97,104,105,108,110.
62	1,20,27,36,39,45,53,71,77,97,104,107,110,118.
63	1,3,8,9,13,15,19,27,33,35,36,39,40,45,49,60,63,70,71,77,97,101, 108,113,118.
64	1,2,3,13,19,20,27,33,40,70,71,77,78,104,107,110,112,113,118.
65	2,13,19,20,21,27,36,40,47,50,56,58,70,77,97,107.

Table 2. (Cont'd)

Stand No.	Plant Species
66	1,13,19,28,38,41,46,58,71,77,89,90,110,113,118.
67	1,15,16,17,18,20,21,27,31,36,53,76,77,97,104,110,118.
68	1,3,11,18,21,31,36,53,60,76,91,95,97,104,108,118.
69	1,3,15,16,17,18,27,53,60,76,97,101,104,106,118.
70	1,3,15,16,17,18,21,27,36,53,76,97,106,110,118.
71	1,3,15,17,18,21,27,36,53, 73,106.
72	3,18,27,31,36,45,53,76,79,82,97,104,106,110,118.
72B	1,3,13,16,17,18,27,36,39,54,76,94,97,104,106,118.
73	1,13,16,19,27,29,36,76,77,83,94,96,97,105,106,107,118.
74	1,3,13,16,27,29,36,71,76,83,86,94,97,107,118.
75	1,3,11,13,15,19,20,27,29,36,53,71,77,79,83,86,101,109,110,118.
76	1,16,17,19,20,27,31,36,39,53,77,78,83,87,97,104,107,110.
77	1,16,18,27,31,36,60,76,77,78,83,97,104,107,110,111,112.
78	1,15,16,18,27,31,36,74,76,77,83,97,101,104,118,
79	6,11,12,17,18,20,21,22,25,27,36,45,64,72,74,77,81,83,91, 108,118.
80	6,7,11,16,17,18,21,22,27,33,36,45,64,77,81,83,91,94.
81	6,7,11,13,15,16,21,22,29,34,36,45,77,79,81,91,94.
82	11,16,18,20,21,27,31,36,45,49,53,64,72,74,77,81,84,91,94,97,107.
83	1,11,16,20,27,36,39,45,72,74,81,83,91,97,108,
84	1,18,27,29,36,45,76,77,79,83,91,104,112.
85	7,18,27,29,36,72,76,78,97,108,118.
86	3,12,15,27,29,36,45,72,77,78,79,97,107,108,112,114,118.
87	1,18,20,21,22,29,36,72,76,77,78,79,94,97,107,112,118.

Table 2. (Cont'd)

Stand No.	Plant Species
88	1,15,18,19,20,21,27,29,31,39,53,72,76,77,78,79,97,107,112,118.
89	1,3,9,19,27,29,36,39,41,76,77,78,79,83,89,97,107,108,110.
90	1,3,9,27,29,31,36,37,39,83,87,97,107,108,110,118.
91	9,27,31,36,38,39,68,82,83,97,107,108,110.
92	1,13,21,27,31,39,60,71,77,107,108,112.
93	1,13,21,27,33,77,104,107,108.
94	1,13,27,29,33,60,77,79,110.
95	1,13,20,27,33,37,60,71,77,97,107,108,110.
96	10,20,27,31,33,71,77,83,97,107,108,110.
97	9,16,19,20,27,29,31,39,41,45,79,81,85,87,97,110,118.
98	9,16,19,27,29,31,36,38,39,41,60,79,81,83,85,87,99,108,110.
99	9,16,19,29,31,37,39,41,66,68,87,97,99,110,118.
100	1,3,19,23,44,59,108,110,118.
101	3,27,33,44,81,92,110,118.
102	1,3,27,59,81,92,104,105,110,118.
103	1,3,19,27,44,59,81,92,104,105,110,118.
104	1,3,27,35,44,76,81,92,104,110,118.
105	1,3,35,44,59,76,81,92,104,110,118.
106	3,4,38,59,76,105,110.
107	3,13,38,51,59,87,88,93,104,110,118.
108	3,13,16,38,51,88.
109	3,13,16,38,44,51,67,87,88,104,118.
110.	3,13,16,38,44,51,67,104,108.
111	3,13,16,38,44,51,67,104,118.

Table 2. (Cont'd)

Stand No.	Plant Species
112	1,3,13,16,38,51,67,104,118.
113	1,3,13,20,21,27,33,39,77,83,94,95,96,97,107.
114	1,3,10,20,21,27,36,39,42,53,77,81,83,94,97,107.
115	1,3,10,21,27,33,36,53,54,72,77,83,94,97,107.
116	1,3,21,27,36,39,53,54,72,77,83,94,97,107.
117	1,3,20,21,27,39,53,54,72,77,83,94,97,107.
118	1,2,3,27,36,39,54,77,81,83,94,97,116.

Table 3. Environmental Parameters

Stand No.	Slope in °.	Aspect	Altitude	Locality
1	1	S	2600	Bedi
2	"	"	"	
3	"	"	"	"
4	"	"	"	"
5	"	"	"	"
6	"	"	"	"
7	"	"	"	"
8	"	"	"	"
9	10	W	2450	Berfeta
10	7	NW	"	"
11	9	"	"	"
12	6	NW	"	"
13	9	W	2500	"
14	4	S	2400	Holeta IAR
15	2	S	"	"
16	"	"	"	"
17	"	"	"	"
18	0	-	"	"
19	4	-	"	Holeta town
20	5	S	"	"
21	3	"	"	"
22	3	"	"	"
23	2	"	"	"
24	2	"	2600	Wodo gay

Table 3. (Cont'd)

Stand No.	Slope	Aspect	Altitude	Locality
25	0	-	2600	Wodo gay
26	1	S	"	"
27	2	"	"	"
28	5	"	"	"
29	6	"	"	"
30	0	E	"	"
31	0	-	"	"
32	4	S	"	"
33	0	-	"	"
34	0	-	"	Kuyu eke
35	"	-	"	"
36	9	SE	"	"
37	1.5	"	"	"
38	0	-	"	"
39	0	-	"	"
40	5	SE	"	"
41	4.5	"	"	"
42	0	-	2350	Roge
43	"	"	"	"
44	-	-	-	-
45	0	-	2350	Roge
46	"	"	"	"
47	0	-	"	"
47B	0	-	"	"
48	2	NW	"	"

Table 3. (Cont'd)

Stand No.	Slope	Aspect	Altitude	Locality
49	7	S	2400	Holeta dairy farm
50	3	S	2400	Holeta dairy farm
51	5	"	"	"
52	0	-	"	"
53	4	S	"	"
53B	4	S	"	"
54	0	-	2550	Gefersa reservoir
55	"	-	"	"
56	"	-	"	"
57	"	"	"	"
58	"	"	"	"
59	"	"	"	"
60	6	E	"	Gefersa West of the reservoir
61	6	"	"	"
62	15	SE	"	"
63	32	W	"	"
64	9	NW	"	"
65	23	"	"	"
66	15	"	"	"
67	4	S	2450	Gida
68	5	S	"	"
69	2	S	"	"
70	1	"	"	"
71	5	"	"	"

Table 3. (Cont'd)

Stand No.	Slope	Aspect	Altitude	Locality
72	7	S	2450	Gida
72B	7	"	"	"
73	0	-	2350	Kawo
74	0	-	"	"
75	0	-	"	"
76	12	N	2325	"
77	12	N	"	"
78	12	"	"	"
79	0	-	2250	Kumbure
80	0	-	"	"
81	0	-	"	"
82	"	-	"	"
83	"	"	"	"
84	"	"	"	"
85	"	"	"	"
86	"	"	"	"
87	"	"	"	"
88	"	"	"	"
89	"	"	2450	Dobi
90	"	"	"	"
91	"	"	"	"
92	"	"	"	"
93	"	"	"	"
94	"	"	"	"
95	"	"	"	"

Table 3. (Cont'd)

Stand No.	Slope	Aspect	Altitude	Locality
96	0	-	2450	Dobi
97	"	"	"	"
98	"	"	"	"
99	"	"	"	"
100	"	"	2600	Bedi
101	"	"	"	"
102	"	"	"	"
103	"	"	"	"
104	"	"	"	"
105	"	"	"	"
106	"	"	"	"
107	"	"	"	"
108	"	"	"	"
109	"	"	"	"
110	"	"	"	"
111	"	"	"	"
112	"	"	"	"
113	3	S	2250	Wagidi
114	5	"	"	"
115	4	"	"	"
116	9	"	"	"
117	5	"	"	"
118	5	"	"	"

Table 4. Grazing and Drainage Conditions in Wolmera Grasslands

Stand No.	Discription
1 - 5	intensively grazed and freely drained
6 - 8	intensively grazed, fallowed from 2-5 years and freely drained.
9	intensively grazed and freely drained
10	intensively grazed, fallowed from 2-5 years and freely drained
11 - 13	intensively grazed and freely drained
14 - 18	not grazed, mowed regularily and water logged during the rainy season only.
19 - 23	intensively grazed and freely drained
24 - 29	intensively grazed and water logged during the rainy season only
30-33	intensively grazed, fallowed from 2-5 years and freely drained.
34 - 35	intensively grazed and freely drained.
36 - 40	moderately grazed, fallowed from 2-5 years and freely drained.
41	moderately grazed and freely drained
42 - 48	intensively grazed and water logged during the rainy season only
49 - 53	not grazed, mowed regularily and water logged during the rainy season only

Table 4. (Cont'd)

Stand No.	Discription
54 - 59	not mowed regularily, not grazed and freely drained.
60-66 m	moderately grazed and freely drained.
67 - 72B	not grazed during the rainy season and water logged during the rainy season
73 - 78	moderately grazed and freely drained
79 - 83	intensively grazed and water logged during the rainy season only.
84 - 88	moderately grazed, fallowed from 2-5 years and water logged during the rainy season only
89 - 91	moderately grazed, fallowed from 2-5 years and freely drained.
92-96	intensively grazed and freely drained.
97 - 99	moderately grazed, fallowed from 2-5 years and freely drained
100 - 112	not grazed, not mowed regularily and permanently water logged.
113 - 118	intensively grazed freely drained.

Table 5. Soil Color 'YR) at Various Depth

Depth in cm / Stand No.	0-10	10-20	20-30	30-40	40-50	50-60	60-70
1d	7.5 4/2	10 4/3	5.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 3/2
w	5 3/2	5 3/2	5 2/2	5 3/2	5 2/2	5 3/2	5 3/2
2d	10 4/3	10 4/3	7.5 3/2	7.5 3/2	7.5 4/2	----	----
w	7.5 3/2	7.5 3/2	5 3/2	5 3/2	5 2/3	----	----
3d	10 4/3	10 4/4	10 3/4	7.5 4/2	7.5 4/2	10 4/3	7.5 4/3
w	10 3/2	10 3/2	10 3/3	7.5 3/2	10 3/2	10 3/2	7.5 3/2
4d	7.5 4/4	7.5 4/4	7.5 4/2	7.5 4/2	7.5 3/2	7.5 3/2	7.5 3/2
w	7.5 3/2	77.5 3/2	7.5 3/2	7.5 3/2	7.5 3/3	5 3/2	5 3/2
5d	7.5 4/4	7.5 4/4	7.5 4/4	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2
w	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	5 3/2	5 3/2
6d	7.5 4/2	7.5 4/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 4/2
w	5 3/2	7.5 3/2	5 3/1	5 3/1	5 2/2	5 2/2	5 3/2
7d	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/4
w	5 3/2	5 3/2	5 3/2	5 3/2	5 3/2	5 3/2	7.5 4/2
8d	10 4/3	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2
w	7.5 3/2	7.5 3/2	7.5 3/2	5 3/2	5 3/2	5 3/2	5 3/2
9d	5 3/3	2.5 3/4	2.5 3/4	5 3/4	5 3/4	5 3/4	5 3/4
w	5 3/2	5 3/3	2.5 3/2	2.5 3/2	2.5 3/2	2.5 3/2	5 3/2
10d	5 3/4	5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4
w	5 3/2	2.5 3/2	2.5 3/2	2.5 3/2	2.5 3/2	2.5 3/2	2.5 3/2
11d	5 3/4	5 3/3	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4
w	5 3/2	5 3/2	2.5 3/2	2.5 3/4	2.5 3/2	2.5 3/2	2.5 3/2

Table 5. (Cont'd)

Depth in cm / Stand No.	0-10	10-20	20-30	30-40	40-50	50-60	60-70
12d	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4
w	2.5 3/2	2.5 3/2	2.5 3/4	2.5 3/2	5 3/2	5 3/3	2.5 3/4
13d	7.5 3/2	7.5 3/2	5 3/2	5 3/3	5 3/2	7.5 3/2	----
w	5 3/1	5 3/1	5 3/1	5 3/2	5 2/2	5 3/2	----
14d	10 3/3	10 3/3	10 3/4	10 3/4	10 3/3	10 3/3	10 3/3
w	10 3/2	10 3/2	10 3/2	10 3/3	10 3/3	10 3/3	10 3/2
15d	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/3
w	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2
16d	10 3/2	10 3/3	10 3/3	10 3/2	2.5 3/2	----	----
w	10 3/2	10 3/3	10 3/3	10 3/3	2.5 3/2	----	----
17d	10 3/3	10 3/3	10 3/2	10 3/2	10 3/3	----	----
w	10 3/2	10 3/2	10 3/2	10 3/3	10 3/3	----	----
18d	10 3/2	10 3/2	10 3/2	10 2/2	10 3/2	10 3/2	10 3/1
w	10 3/2	10 3/2	10 3/2	10 2/2	10 3/2	10 3/2	10 3/1
19d	----	----	----	----	----	----	----
w	----	----	----	----	----	----	----
20d	7.5 4/2	7.5 4/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2
w	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2
21d	10 3/3	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2
w	10 2/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	10 2/2	5 2/2
22d	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2
w	5 3/2	7.5 3/2	10 2/2	7.5 3/2	5 2/2	7.5 3/2	7.5 3/2
23d	5 3/4	5 3/4	5 3/4	7.5 3/2	7.5 4/2	5 3/3	5 3/3
w	5 3/2	5 3/2	5 3/3	5 3/2	7.5 3/2	5 3/3	5 3/3

Table 5. (Cont'd)

Depth in cm / Stand No.	0-10	10-20	20-30	30-40	40-50	50-60	60-70
24d	10 3/3	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	----
w	10 4/2	7.5 3/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	----
25d	----	----	----	----	----	----	----
w	----	----	----	----	----	----	----
26d	10 3/2	10 3/3	10 3/4	----	----	----	----
w	10 2/2	10 3/3	10 3/4	----	----	----	----
27d	10 4/2	7.5 4/2	7.5 4/2	7.5 4/4	7.5 4/2	7.5 4/2	----
w	10 2/2	10 2/2	10 3/2	10 3/2	10 3/2	----	----
28d	7.5 4/2	7.5 3/2	7.5 4/2	7.5 4/2	7.5 4/4	7.5 4/2	----
w	7.5 3/2	10 3/3	7.5 3/2	7.5 4/4	7.5 4/4	7.5 4/2	----
29d	10 3/2	5 3/3	7.5 4/2	7.5 4/2	10 3/3	----	----
w	10 3/2	5 3/2	7.5 4/2	7.5 4/2	10 3/3	----	----
30d	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 4/2
w	7.5 3/2	5 2/2	5 2/2	5 2/2	5 2/2	5 2/2	5 2/2
31d	7.5 4/2	5.5 4/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 4/2	7.5 4/2
w	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2
32d	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/4	7.5 4/4	7.5 4/4
w	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 4/4	7.5 4/4	7.5 4/4
33d	7.5 4/3	7.5 3/2	5 3/4	5 3/4	5 3/4	5 3/4	5 3/4
w	7.5 3/2	7.5 3/2	5 3/3	5 3/3	5 3/3	5 3/4	5 3/4
34d	5 3/4	5 3/4	5 3/4	----	----	----	----
w	5 3/3	5 3/3	5 3/3	----	----	----	----

Table 5. (Cont'd)

Depth in cm / Stand No.	0-10	10-20	20-30	30-40	40-50	50-60	60-70
35d	5 4/4	5 4/4	5 3/4	5 3/4	5 3/4	5 3/4	5 4/4
w	5 3/4	5 3/4	5 3/3	5 3/3	5 3/4	5 3/4	5 3/4
36d	7.5 4/2	7.5 4/4	5 3/4	5 3/4	5 3/4	5 3/2	5 3/2
w	7.5 3/2	5 3/3	5 3/3	5 3/3	5 3/3	5 3/2	5 2/2
37d	5 4/4	5 3/4	5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4
w	5 3/4	5 3/3	5 3/3	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4
38d	5 3/4	5 4/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4
w	5 3/3	5 3/3	5 3/3	5 3/4	5 3/4	2.5 3/4	2.5 3/4
39d	5 3/4	5 4/4	5 4/4	2.5 3/4	2.5 4/4	2.5 3/4	2.5 3/4
w	5 3/3	5 3/4	5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4
40d	5 4/4	5 4/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4
w	5 3/4	5 3/4	2.5 3/2	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4
41d	7.5 4/2	7.5 3/2	5 4/4	5 4/4	5 4/4	5 3/3	5 3/3
w	7.5 3/2	5 3/2	5 3/3	5 3/3	5 3/4	5 3/3	5 3/2
42d	10 2/2	10 2/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2
w	10 2/1	10 2/1	10 2/2	10 3/2	10 3/2	10 3/2	10 3/2
42Bd	10 3/2	10 3/2	10 3/2	10 3/2	10 3/3	10 3/3	10 3/3
w	10 2/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2
43d	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2
w	10 2/2	10 2/2	10 2/2	10 2/2	10 3/2	10 3/2	10 3/2
44d	----	----	----	----	----	----	----
w	----	----	----	----	----	----	----
45d	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2
w	10 2/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2

Table 5. (Cont'd)

Depth in cm / Stand No.	0-10	10-20	20-30	30-40	40-50	50-60	60-70
46d	10 3/2	10 3/2	10 3/2	10 3/2	10 3/1	10 3/1	10 3/1
w	10 3/2	10 3/2	10 3/2	10 3/2	10 3/1	10 3/1	10 3/1
47d	10 4/3	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2
w	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2
47Bd	10 3/2	10 3/1	10 3/1	10 3/1	10 3/1	10 3/1	10 3/1
w	10 3/2	10 3/1	10 3/1	10 3/1	10 3/1	10 3/1	10 3/1
48d	7.5 4/4	7.5 4/4	7.5 4/4	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2
w	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2
49d	10 3/2	7.5 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2
w	10 2/2	10 2/2	10 2/2	10 2/2	10 2/2	10 3/2	10 3/2
50d	10 4/2	7.5 3/2	10 4/2	10 4/2	10 4/2	10 4/2	10 4/2
w	7.5 3/1	7.5 2/2	10 3/2	10 3/2	10 3/2	10 3/3	10 3/3
51d	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2
w	10 2/2	10 2/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2
52d	7.5 4/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2
w	7.5 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2
53d	10 3/3	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2
w	10 2/2	10 3/2	10 3/3	10 3/2	10 3/2	10 3/2	10 3/2
53Bd	10 3/3	10 3/3	10 3/3	10 3/3	10 3/1	10 2/2	10 2/2
w	10 2/2	10 2/2	10 3/3	10 3/2	10 3/1	10 2/1	10 2/2
54d	7.5 4/2	7.5 4/4	10 5/4	7.5 4/4	7.5 4/4	7.5 4/4	7.5 3/2
w	7.5 4/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2
55d	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/4	7.5 4/2	7.5 4/2	5 3/2
w	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	5 3/2

Table 5. (Cont'd)

Depth in cm / Stand No.	0-10	10-20	20-30	30-40	40-50	50-60	60-70
56d	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/4	7.5 4/4	7.5 4/4	5 3/4
w	5 2/2	5 2/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	5 3/4
57d	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/4	7.5 4/4	7.5 4/4	7.5 4/4
w	5 2/2	5 2/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2
58d	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2
w	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2
59d	7.5 4/2	7.5 4/4	7.5 4/4	7.5 4/4	7.5 4/4	7.5 4/4	7.5 4/4
w	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2
60d	7.5 4/4	7.5 4/4	7.5 4/4	5 3/4	5 3/4	5 3/4	5 3/2
w	7.5 3/2	7.5 3/2	7.5 3/2	5 3/2	5 3/2	5 3/2	5 3/2
61d	7.5 4/4	7.5 4/4	7.5 4/4	7.5 4/2	7.5 3/2	7.5 3/2	7.5 3/2
w	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2
62d	----	----	----	----	----	----	----
w	----	----	----	----	----	----	----
63d	----	----	----	----	----	----	----
w	----	----	----	----	----	----	----
64d	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	----	----	----
w	5 2/2	5 2/2	5 2/2	5 2/2	----	----	----
65d	7.5 4/2	7.5 4/2	----	----	----	----	----
w	5 2/2	5 2/2	----	----	----	----	----
66d	----	----	----	----	----	----	----
w	----	----	----	----	----	----	----
67d	10 3/1	10 3/1	10 3/1	----	----	----	----
w	10 2/2	10 2/2	10 2/2	----	----	----	----

Table 5. (Cont'd)

Depth in cm / Stand No.	0-10	10-20	20-30	30-40	40-50	50-60	60-70
68d	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	-----
w	10 2/2	10 2/2	7.5 3/2	10 3/2	10 3/2	10 3/2	-----
69d	10 3/3	10 3/2	10 3/3	10 3/2	10 3/2	10 3/2	10 3/1
w	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/1
70d	10 3/3	10 3/2	10 4/1	10 4/1	-----	-----	-----
w	10 3/2	10 3/2	10 3/1	10 3/1	-----	-----	-----
71d	7.5 3/2	7.5 3/2	7.5 4/2	7.5 4/2	10 3/2	10 3/1	10 3/1
w	7.5 3/2	5 2/2	7.5 3/2	7.5 3/2	10 3/2	10 3/2	10 3/2
72d	7.5 4/2	7.5 4/2	10 3/2	-----	-----	-----	-----
w	7.5 3/2	7.5 3/2	10 3/2	-----	-----	-----	-----
74Bd	5 3/4	5 3/4	5 3/4	7.5 4/2	7.5 4/2	10 3/3	7.5 4/2
w	5 3/3	5 3/3	5 3/2	5 3/2	7.5 4/2	10 3/3	10 3/3
73d	5 3/4	5 3/4	5 3/4	5 3/4	5 3/4	5 3/4	7.5 4/2
w	5 3/3	5 3/2	5 3/2	5 3/2	5 3/2	5 3/2	5 3/2
74d	7.5 4/4	7.5 4/2	7.5 4/4	7.5 4/4	7.5 4/4	7.5 4/4	7.5 4/2
w	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2
75d	5 3/4	5 3/4	5 3/4	5 3/4	5 3/3	5 3/3	5 3/3
w	5 3/2	5 3/2	5 3/2	5 3/2	5 3/2	5 3/2	5 3/2
76d	7.5 4/2	7.5 3/2	5 3/1	5 3/1	5 3/1	10 2/2	10 2/2
w	5 2/2	5 2/2	5 3/1	5 3/1	10 2/2	10 2/2	10 2/2
77d	7.5 4/2	7.5 3/2	7.5 4/2	7.5 4/2	7.5 4/2	10 3/3	10 3/1
w	7.5 3/2	5 2/2	5 2/2	5 3/1	5 3/1	10 3/2	10 2/2
78d	10 3/1	10 4/1	10 4/1	10 4/2	10 4/2	10 4/2	10 4/2
w	10 3/2	10 3/1	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2

Table 5. (Cont'd)

Depth in cm / Stand No.	0-10	10-20	20-30	30-40	40-50	50-60	60-70
79d	10 4/1	10 4/1	10 3/1	10 3/1	10 3/1	10 3/1	10 3/1
w	10 3/1	10 3/1	10 3/1	10 3/1	10 3/1	10 3/1	10 3/1
80d	10 3/2	10 3/1	10 3/1	10 3/1	10 3/1	10 3/1	10 3/1
w	10 2/2	10 3/2	10 3/1	10 3/1	10 3/1	10 3/1	10 3/1
81d	10 4/1	10 4/1	10 3/2	10 4/2	10 4/2	10 6/1	10 5/2
w	10 3/2	10 3/2	10 3/2	10 4/2	10 4/2	10 5/2	10 5/2
82d	10 3/1	10 4/1	10 3/1	10 3/1	10 3/1	10 3/1	10 3/1
w	10 3/1	10 3/1	10 3/1	10 3/1	10 3/1	10 3/1	10 3/1
83d	10 4/1	10 3/1	10 3/1	10 3/1	10 3/1	----	----
w	10 3/1	10 3/1	10 3/1	10 3/1	10 3/1	----	----
84d	10 4/1	10 4/1	10 4/1	10 4/1	10 4/1	10 4/1	10 4/1
w	10 3/1	10 3/2	10 3/2	10 3/2	10 3/1	10 3/1	10 3/2
85d	10 3/3	10 4/2	----	----	----	----	----
w	10 3/2	10 3/2	----	----	----	----	----
86d	10 4/2	10 4/2	10 4/1	----	----	----	----
w	10 3/2	10 3/2	10 3/2	----	----	----	----
87d	10 4/2	10 4/2	10 4/2	----	----	----	----
w	10 3/2	10 3/2	10 3/2	----	----	----	----
88d	10 4/2	10 4/2	10 4/2	10 4/2	10 4/2	10 4/2	10 4/2
w	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2	10 3/2
89d	5 4/2	5 4/2	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 4/4
w	5 3/3	5 3/2	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4
90d	5 3/4	5 4/2	5 3/3	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4
w	5 3/3	5 3/2	5 3/3	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4

Table 5. (Cont'd)

Depth in cm / Stand No.	0-10	10-20	20-30	30-40	40-50	50-60	60-70
91d	5 3/4	5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4
w	5 3/3	5 3/3	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4
92d	7.5 4/2	7.5 3/2	7.5 3/2	7.5 3/2	7,5 3/2	7.5 3/2	7.5 3/2
w	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 2/2	7.5 2/2	7.5 2/2
93d	7.5 4/2	7.5 3/2	7.5 3/2	5 3/2	5 3/2	5 3/2	5 3/2
w	7.5 3/2	5 3/2	5 3/2	5 3/2	5 3/2	5 3/2	5 3/2
94d	7.5 4/2	5 3/4	5 3/3	5 3/2	5 3/2	5 3/2	5 3/2
w	7.5 3/2	5 3/2	5 3/2	5 3/2	5 3/2	5 3/2	5 3/2
95d	7.5 4/4	7.5 4/2	5 3/4	5 3/4	5 3/4	5 3/3	5 3/3
w	7.5 3/2	7.5 3/2	5 3/2	5 3/2	5 3/2	5 3/2	5 3/2
96d	5 4/4	5 4/4	5 4/4	5 4/4	2.5 3/4	2.5 3/4	2.5 3/4
w	5 3/3	5 3/3	5 3/3	5 3/3	2.5 3/4	2.5 3/4	2.5 3/4
97d	5 3/4	5 3/4	5 3/4	5 3/4	5 3/4	5 3/3	5 3/3
w	2.5 2/4	5 3/2	5 3/3	5 3/2	5 3/3	5 3/4	5 3/2
98d	5 3/3	2.5 3/4	2.5 3/4	5 3/4	----	----	----
w	5 3/4	2.5 3/2	2.5 3/2	5 3/2	----	----	----
99d	5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4
w	5 3/3	2.5 3/2	2.5 3/2	2.5 3/2	2.5 3/4	2.5 3/4	2.5 3/4
100d	7.5 4/2	7.5 4/2	10 4/2	10 4/2	----	----	----
w	7.5 3/2	7.5 3/2	10 3/2	10 3/2	----	----	----
101d	7.5 4/2	7.5 4/2	5 4/4	5 4/4	5 4/4	5 4/4	5 3/3
w	7.5 3/2	7.5 3/2	5 3/3	5 3/3	5 3/3	5 3/3	5 3/2
102d	10 4/3	7.5 4/2	7.5 4/4	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2
w	10 3/3	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2

Table 5. (Cont'd)

Depth in cm / Stand No.	0-10	10-20	20-30	30-40	40-50	50-60	60-70
103d	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2
w	7.5 3.2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2
104d	7.5 4/2	7.5 4/2	7.5 4/2	5 4/4	5 4/2	5 3/2	5 3/2
w	7.5 3/2	7.5 3/2	7.5 3/2	5 3/4	5 3/2	5 2/2	5 2/2
105d	7.5 4/4	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2	7.5 4/2
w	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2	7.5 3/2
106d	7.5 4/2	7.5 4/2	7.5 4/2	5 4/2	5 4/2	5 4/2	5 4/2
w	7.5 3/2	7.5 3/2	7.5 3/2	5 3/2	5 3/2	5 3/2	5 3/2
113d	5 4/2	5 4/2	5 4/1	5 4/1	5 4/1	5 3/1	5 3/1
w	5 3/2	5 3/2	5 3/1	5 3/1	5 3/1	5 2/1	5 2/1
114d	7.5 4/2	7.5 3/2	7.5 3/2	7.5 3/2	10 3/1	10 3/1	10 3/1
w	7.5 3/2	10 2/2	10 2/2	10 2/2	10 2/1	10 2/1	10 2/1
115d	2.5 3/4	2.5 3/4	2.5 3/4	7.5 3/2	7.5 3/2	7.5 4/2	10 3/1
w	2.5 2/4	2.5 2/4	2.5 2/4	7.5 2/2	7.5 2/2	7.5 3/2	10 2/1
116d	2.5 3/4	2.5 3/4	2.5 3/4	7.5 3/4	7.5 3/4	5 3/3	5 3/3
w	2.5 2/4	2.5 2/2	2.5 2/4	2.5 2/4	2.5 2/4	5 2/3	5 2/3
117d	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/4	2.5 3/2	7.5 3/2	5 2/3
w	2.5 2/4	2.5 2/4	2.5 2/4	2.5 2/4	2.5 2/2	7.5 2/2	2.5 2/4
118d	5 4/4	5 4/4	5 4/4	2.5 3/4	5 4/4	5 3/3	5 3/3
w	5 3/4	5 3/4	5 3/4	2.5 2/4	5 3/4	5 2/3	5 2/3

Table 6. pH of the Soil Samples at Various Depth

Depth in cm / Stand No.	0-10	20-30	40-50	60-70
1	5.5	5.5	5.5	5.5
2	5.3	5.6	5.6	H.R.
3	5.7	5.5	5.5	5.7
4	5.5	5.5	5.5	5.7
5	5.2	5.2	5.2	5.2
6	5.4	5.5	5.5	5.5
7	5.5	5.6	5.6	5.6
8	5.3	5.5	5.6	5.6
9	5.3	6.0	6.2	6.2
10	5.3	5.7	5.8	6.0
11	5.3	5.6	5.7	5.7
12	5.3	5.2	4.8	4.8
13	5.8	5.8	5.8	5.1
14	5.3	5.5	5.7	6.2
15	5.3	5.7	5.5	5.4
16	5.3	5.5	6.0	D.A.
17	5.1	5.4	5.6	D.A.
18	5.3	5.4	5.5	5.5
19	H.R.	H.R.	H.R.	H.R.
20	5.3	5.2	5.1	5.1
21	5.2	5.2	5.2	5.2
22	5.2	5.2	5.1	5.1

Table 6. (Cont'd)

Depth in cm / Stand No.	0-10	20-30	40-50	60-70
23	5.2	5.0	5.3	5.3
24	5.2	4.8	4.8	W.T.
25	T.W.L.	T.W.L.	T.W.L.	T.W.L.
26	5.1	4.8	W.T.	W.T.
27	4.9	4.6	4.8	W.T.
28	5.0	5.3	5.0	W.T.
29	5.5	5.3	5.3	5.3
30	5.0	4.8	4.8	4.9
31	5.0	5.2	5.0	4.9
32	4.9	4.8	4.7	4.9
33	4.5	4.9	5.1	5.0
34	5.0	5.0	H.R.	H.R.
35	4.5	5.1	5.2	5.2
36	4.7	5.0	5.0	5.0
37	5.0	5.0	5.2	5.3
38	4.9	5.0	5.2	5.2
39	5.2	5.0	5.0	5.2
40	5.2	5.1	5.4	5.4
41	5.1	5.0	5.1	5.0
42	5.4	5.5	5.5	5.6
43	5.5	5.6	6.0	5.6
44	N.S.	N.S.	N.S.	N.S.
45	6.0	6.5	6.3	6.8

Table 6. (Cont'd)

Depth in cm / Stand No.	0-10	20-30	40-50	60-70
46	5.3	5.5	5.8	6.3
47	5.3	5.7	6.0	6.2
48	5.6	5.3	5.4	5.5
49	5.4	5.3	5.3	5.2
50	5.0	5.8	6.4	7.2
51	5.1	5.3	5.5	6.0
52	5.0	5.4	6.1	6.5
53	5.4	6.0	6.1	6.4
53B	5.1	6.0	6.4	7.0
54	5.3	5.2	5.1	5.2
55	5.5	5.1	5.1	5.5
56	5.0	5.0	5.1	5.1
57	5.0	5.4	5.4	5.5
58	4.9	5.1	5.4	5.6
59	4.9	5.0	5.2	5.4
60	5.1	5.1	5.3	5.5
61	5.0	5.2	5.3	5.3
62	H.R.	H.R.	H.R.	H.R.
63	H.R.	H.R.	H.R.	H.R.
64	5.3	5.4	H.R.	H.R.
65	5.1	H.R.	H.R.	H.R.
66	H.R.	H.R.	H.R.	H.R.
67	5.6	7.4*	D.A.	D.A.
68	4.9	4.9	4.9	D.A.

Table 6. (Cont'd)

Depth in cm / Stand No.	0-10	20-30	40-50	60-70
92	5.0	5.1	5.1	5.1
93	4.9	5.1	5.0	4.9
94	4.6	4.9	4.9	5.0
95	4.6	4.7	4.9	4.9
96	5.0	5.0	5.1	5.4
97	5.6	5.0	5.1	5.1
98	5.7	6.1	H.R.	H.R.
99	5.8	6.0	6.0	6.1
100	4.7	5.7	H.R.	H.R.
101	4.1	4.6	5.2	5.4
102	4.3	4.4	4.6	5.0
103	4.3	4.6	6.6	6.7
104	4.6	4.6	5.1	5.4
105	4.7	4.8	6.7	6.7
106	4.5	5.0	5.2	5.0
107	P.W.L.	P.W.L.	P.W.L.	P.W.L.
108	"	" "	" "	" "
109	" "	" "	" "	" "
110	" "	" "	" "	" "
111	" "	" "	" "	" "
112	" "	" "	" "	" "
113	5.5	5.6	5.7	5.8
114	5.6	6.0	6.3	6.7

Table 6. (Cont'd)

Depth in cm / Stand No.	0-10	20-30	40-50	60-70
69	4.8	5.2	5.2	5.0
70	4.8	5.2	D.A.	D.A.
71	4.8	5.1	5.1	5.6
72	4.6	5.1	D.A.	D.A.
72B	5.2	5.0	5.2	5.6
73	S.L.	5.0	5.5	5.6
74	5.2	5.1	5.3	5.6
75	5.0	4.8	4.8	4.5
76	5.2	5.2	5.3	5.5
77	5.1	5.4	5.2	H.R.
78	5.4	5.5	6.2	6.5
79	5.5	5.7	6.2	H.R.
80	5.4	6.0	7.0	7.5
81	5.0	6.0	6.3	7.4
82	5.8	6.3	7.2	7.8
83	5.8	6.0	D.A.	D.A.
84	5.7	6.5	7.0	7.6
85	5.6	6.4	D.A.	D.A.
86	5.7	5.7	D.A.	D.A.
87	5.3	5.7	D.A.	D.A.
88	5.3	5.3	5.3	5.8
89	5.1	5.2	5.5	5.5
90	4.9	5.2	5.5	5.4
91	5.1	5.2	5.5	5.4

Table 6. (Cont'd)

Depth in cm

Stand No.	0-10	20-30	40-50	60-70
115	7.7	6.0	5.8	6.1
116	5.3	5.4	5.4	5.3
117	5.6	5.3	5.5	5.8
118	5.7	5.5	5.6	6.0

Key to the symbols

W.T. = Water Table

T.W.L. = Temporarily Water Logged

N.S. = No Sample

H.R. = Hard rock

S.A. = Difficult to Augar

P.W.L. = Permanently Water Logged.

Table 7. Electrical Conductivity of the Soil Samples at Various Depth in mmhos /cm

Depth in cm / Stand No.	0-10	20-30	40-50	60-70
1	12.37	7.16	8.43	8.43
2	20.40	7.20	7.34	H.R.
3	5.71	7.16	9.52	12.51
4	6.75	7.82	9.65	8.43
5	6.93	10.60	10.88	19.04
6	13.60	10.60	9.79	10.36
7	8.84	8.16	9.79	7.88
8	11.28	11.42	11.69	13.05
9	24.48	20.40	24.48	20.40
10	17.68	17.68	19.04	20.40
11	21.76	19.04	16.32	16.32
12	17.00	10.88	10.60	10.88
13	21.76	17.68	17.68	17.68
14	16.32	24.48	27.20	27.20
15	23.88	29.92	25.84	24.48
16	17.68	24.48	29.92	D.A.
17	23.80	24.48	27.20	"
18	21.76	21.76	21.76	27.20
19	T.W.L.	T.W.L.	T.W.L.	T.W.L.
20	12.24	19.04	23.12	27.20
21	16.32	14.92	17.68	24.48
22	13.60	16.32	23.12	29.92

Table 7. (Cont'd)

Depth in cm / Stand No.	0-10	20-30	40-50	60-70
23	25.84	20.40	10.06	19.04
24	13.60	19.04	14.92	W.T.
25	W.T.	W.T.	W.T.	T.W.L.
26	8.16	14.96	W.T.	W.T.
27	6.93	21.76	24.48	W.T.
28	14.96	12.24	17.68	W.T.
29	21.76	28.56	32.64	W.T.
30	13.60	12.92	19.04	W.T.
31	14.96	13.60	16.32	23.80
32	19.04	17.68	16.32	16.32
33	24.48	24.48	21.76	21.76
34	10.60	12.24	H.R.	H.R.
35	14.96	12.24	16.32	13.60
36	20.40	13.60	16.32	13.60
37	13.60	10.60	12.64	10.47
38	13.60	14.96	14.96	14.96
39	9.52	11.15	7.07	11.28
40	11.69	12.78	11.42	12.64
41	10.06	9.79	13.32	11.28
42	16.32	13.60	24.48	12.78
43	14.96	24.48	11.42	24.48
44	N.S.	N.S.	N.S.	N.S.
45	20.40	20.40	16.32	27.20

Table 7. (Cont'd)

Depth in cm / Stand No.	0-10	20-30	40-50	60-70
46	17.68	19.04	17.68	23.12
47	23.12	10.33	21.76	32.64
48	7.07	8.70	13.60	11.69
49	24.48	20.40	19.04	24.48
50	24.48	24.48	35.36	34.00
51	21.76	23.12	29.92	27.20
52	19.04	21.76	29.92	24.48
53	20.40	16.32	24.48	24.48
53B	21.76	29.92	35.36	28.56
54	9.24	7.34	9.52	8.70
55	12.51	7.34	7.34	7.48
56	10.04	9.24	7.07	7.34
57	21.76	9.52	10.36	8.56
58	16.32	7.75	8.43	13.60
59	9.79	7.61	7.07	8.43
60	7.07	8.16	8.70	10.33
61	7.28	7.75	7.48	9.24
62	H.R.	H.R.	H.R.	H.R.
63	H.R.	H.R.	H.R.	H.R.
64	6.80	11.28	H.R.	H.R.
65	13.60	H.R.	H.R.	H.R.
66	H.R.	H.R.	H.R.	H.R.
67	27.20	59.84	D.A.	D.A.
68	16.32	23.12	19.04	D.A.

Table 7. (Cont'd)

Depth in cm / Stand No.	0-10	20-30	40-50	60-70
69	14.96	19.04	32.64	16.32
70	16.32	20.40	D.A.	D.A.
71	11.42	13.60	25.80	21.76
72	14.96	16.32	D.A.	D.A.
72B	8.43	11.83	16.32	16.32
73	S.L.	10.20	7.48	10.06
74	16.32	8.70	9.24	8.97
75	14.96	11.42	11.01	10.47
76	16.32	16.32	16.32	16.32
77	14.96	12.78	16.32	H.R.
78	23.12	29.92	21.76	4.80
79	13.60	14.96	29.92	H.R.
80	16.32	39.46	46.24	43.52
81	17.68	21.76	19.04	25.84
82	27.20	31.28	34.00	46.24
83	38.08	24.48	D.A.	D.A.
84	35.36	24.48	32.64	40.80
85	16.32	25.84	D.A.	D.A.
86	14.96	21.76	D.A.	D.A.
87	13.60	13.60	D.A.	D.A.
88	14.96	20.40	17.68	19.04
89	10.88	11.69	7.61	11.15
90	12.10	12.92	11.83	10.74

Table 7. (Cont'd)

Depth in cm / Stand No.	0-10	20-30	40-50	60-70
91	13.60	10.20	13.60	12.24
92	8.97	13.32	11.56	13.60
93	11.01	12.92	13.60	9.65
94	10.88	10.20	11.56	10.20
95	10.47	9.52	10.47	13.32
96	8.16	8.02	8.16	8.84
97	14.96	12.24	10.20	13.60
98	19.04	20.40	H.R.	H.R.
99	20.40	19.04	14.96	16.32
100	16.32	16.32	H.R.	H.R.
101	14.96	6.12	9.24	10.20
102	9.92	7.61	6.66	14.96
103	16.32	5.98	8.97	12.78
104	12.24	8.70	6.66	14.96
105	8.29	8.29	9.52	14.96
106	20.40	12.24	6.12	8.97
107	P.W.L.	P.W.L.	P.W.L.	P.W.L.
108	" "	" "	" "	" "
109	" "	" "	" "	" "
110	" "	" "	" "	" "
111	" "	" "	" "	" "
112	" "	" "	" "	" "
113	17.88	16.32	19.04	17.68
114	16.32	24.48	24.48	24.48

Table 7. (Cont'd)

Depth in cm

Stand No.	0-10	20-30	40-50	60-70
115	13.60	10.74	13.60	29.92
116	13.60	11.96	14.96	14.96
117	12.78	10.88	9.52	6.52
118	10.33	10.47	10.06	7.88

Key to symbols

H.R. = Hard Rock

D.A. = Difficult to Auger

T.W.L. = Temporarily Water Logged

W.T. = Water Table

N.S. = No Samples

P.W.L. = Permanently Water Logged

S.L. = Sample lost

Table 8. Cation Content of the Soil Samples in ppm

Stand No.	Sodium Depth 0-10 cm	Sodium Depth 30 - 40 cm	Pottassium Depth 0-10 cm	Pottassium Depth 30 - 40 cm
1	2.18	1.90	12.21	10.56
2	1.87	2.52	18.48	8.58
3	1.90	2.65	13.53	11.22
4	1.97	2.58	11.22	9.90
5	2.31	3.23	10.56	11.88
6	2.18	2.31	20.13	18.15
7	2.18	2.86	11.22	12.21
8	2.38	1.84	11.22	10.89
9	3.06	3.40	53.63	127.05
10	2.45	2.45	60.06	68.48
11	2.92	2.89	60.0	53
12	2.35	2.38	25.08	17.49
13	2.89	2.89	32.01	24.42
14	5.27	7.82	28.38	35.64
15	4.59	5.95	32.34	31.68
16	8.16	5.64	29.37	23.10
17	4.49	7.14	25.74	29.04
18	5.85	7.48	20.46	22.44
19	3.26	4.08	20.79	23.76
20	4.25	3.23	31.68	41.09
21	3.74	3.23	40.26	44.22
22	2.89	3.23	25.08	27.72

Table 8. (Cont'd)

Stand No.	Sodium Depth 0 - 10 cm	Sodium Depth 30 - 40 cm	Pottassium Depth 0 - 10 cm	Pottassium Depth 30 - 40 cm
23	3.40	2.72	22.11	21.45
24	4.42	2.42	14.25	11.55
25	-	-	-	-
26	5.44	-	12.54	-
27	4.76	5.78	20.46	13.20
28	5.44	5.10	16.83	14.52
29	5.95	7.31	11.22	10.56
30	6.12	5.44	11.22	12.87
31	4.93	4.93	8.25	12.54
32	4.59	5.10	12.87	15.18
33	4.93	4.76	11.22	10.56
34	3.19	3.23	24.75	29.70
35	4.08	-	23.76	-
36	4.08	4.08	20.46	21.78
37	3.74	2.89	23.76	20.46
38	3.06	4.42	29.04	21.45
39	3.23	3.40	25.08	23.10
40	3.57	3.57	39.11	31.02
41	4.08	3.57	21.45	14.52
42	5.10	5.10	14.85	14.52
43	6.63	9.35	16.83	23.76
44	-	-	-	-
45	7.65	10.54	25.08	26.40
46	7.14	10.20	21.12	21.78

Table 8. (Cont'd)

Stand No.	Sodium Depth 0 - 10 cm	Sodium Depth 30 - 40 cm	Potassium Depth 0 - 10 cm	Potassium Depth 30 - 40 cm
47	3.91	4.93	24.42	16.17
47B	10.88	13.94	26.73	28.71
48	4.76	5.10	20.79	21.78
49	4.42	4.59	18.48	27.06
50	4.59	5.78	45.38	62.70
51	5.44	5.27	28.38	38.12
52	4.76	5.44	41.25	66.83
53	4.76	6.12	46.20	57.75
53B	5.27	4.76	75.90	115.50
54	3.06	3.75	8.91	27.06
55	3.74	3.40	14.36	7.92
56	3.75	3.40	16.00	10.23
57	3.40	3.74	25.41	8.75
58	3.74	4.08	17.82	9.24
59	4.08	-	11.22	-
60	3.74	3.74	32.34	19.14
61	3.75	4.08	23.76	15.35
62	-	-	-	-
63	-	-	-	-
64	8.16	5.61	5.94	6.27
65	-	-	-	-
66	11.22	11.05	15.18	13.53
67	6.48	-	14.19	-

Table 8. (Cont'd)

Stand No.	Sodium Depth 0 - 10 cm	Sodium Depth 30 - 40 cm	Potassium Depth 0 - 10 cm	Potassium Depth 30 - 40 cm
68	11.90	7.82	13.53	13.53
69	9.01	6.46	12.54	15.18
70	6.97	6.97	12.87	13.86
71	9.52	7.99	11.55	14.85
72	6.63	-	12.21	-
72B	7.14	6.12	13.53	20.46
73	4.25	7.99	27.06	23.10
74	7.82	8.50	39.11	31.19
75	5.44	5.27	44.55	29.37
76	10.20	10.20	27.06	31.35
77	9.86	15.64	22.11	21.45
78	19.04	8.50	30.03	40.59
79	27.20	51.65	20.13	27.72
80	18.70	45.56	16.50	31.68
81	18.02	34.17	20.46	33.17
82	20.74	24.48	26.07	29.70
83	15.98	18.02	20.79	28.38
84	18.70	33.66	37.13	37.12
85	14.62	-	29.04	-
86	15.64	-	21.12	-
87	-	-	19.74	-
88	5.44	13.94	35.46	42.08
89	6.80	9.18	20.46	23.43

Table 8. (Cont'd)

	Sodium		Potassium	
Stand	Depth	Depth	Depth	Depth
No.	0 - 10 cm	30 - 40 cm	0 - 10 cm	30 - 40 cm
90	5.10	8.16	24.75	29.43
91	3.06	6.80	29.37	36.63
92	5.95	5.61	9.24	8.58
93	6.29	6.46	9.90	8.91
94	4.08	6.63	15.18	12.21
95	3.40	5.10	15.51	8.58
96	3.40	6.97	29.70	18.48
97	3.91	4.93	6.93	14.19
98	5.61	4.08	45.54	31.68
99	4.25	5.44	45.54	52.80
100	4.62	4.76	12.87	26.40
101	6.63	5.30	9.90	21.12
102	4.62	5.77	14.85	8.58
103	5.58	4.15	13.84	6.60
104	6.64	3.33	9.90	7.92
105	5.30	4.35	9.24	19.14
106	5.44	11.39	9.90	8.91
107	-	-	-	-
108	-	-	-	-
109	-	-	-	-
110	-	-	-	-
111	-	-	-	-
112	-	-	-	-

Table 8. (Cont'd)

	Sodium		Potassium	
Stand	Depth	Depth	Depth	Depth
No.	0 - 10 cm	30 - 40 cm	0 - 10 cm	30 - 40 cm
113	8.16	9.18	25.74	25.08
114	8.33	13.26	24.75	29.04
115	4.22	6.97	23.43	26.40
116	4.22	7.99	19.47	14.52
117	3.26	5.85	25.74	25.08
118	4.15	5.64	38.61	34.65

5. RESULTS

5.1 The Vegetation Types

Comparing the raw environmental data and the results of the association analysis classification, it was felt that useful comparisons resulting in distinct environments with their respective vegetations would give a meaningful picture of the grasslands.

These comparisons were carried out among the following catagories of classificatory hierarchy.

Group A is identified by the absence of Vigna sp. and the presence of Haplocarpha ? hastata consisting of 5 stands all in a marsh. The stands in this group are 107, 108, 109, 110 and 111. Soil samples were not collected from these stands because the marshy condition made it impracticable. Comparisons based on soil data will exclude this group.

Group B is identified by the absence of Vigna sp., the abcence of Haplocarpha ? hastata and the presence of Andropogon pratensis, consisting of 44 stands. The stands in this group are 14, 15, 16, 17, 18, 25, 42, 43, 45, 46, 47B, 49, 50, 51, 52, 53, 53B, 61, 63, 64, 66, 69, 70, 71, 72, 72B, 74, 86, 89, 90, 100, 101, 102, 103, 104, 105, 106, 112, 113, 114, 115, 116, 117 and 118. It is 3rd in pH at the surface and 2nd at 40 - 50 cm depth, but 2nd in pH average for the surface and 40 - 50 cm depth, 2nd in conductivity at both depths, 2nd in hue 3rd in chroma, 2nd in value, 2nd in sodium, 3rd in potassium and 2nd in slope.

Group C is identified by the absence of Vigna sp, the absence of Haplocarpha hastata, the absence of Andropogon pratensis and the presence of Scleria hispidior, consisting of 7 stands. The stands in this group are 67, 76, 77, 78, 84, 85, and 86. It ranked 1^{st} in pH, 1^{st} in conductivity, 1^{st} in hue, 2^{nd} in chroma at the surface and 1^{st} at 30 - 40 cm but 2^{nd} in average chroma, 3^{rd} in value, 1^{st} in sodium and potassium, 1^{st} in slope.

Group D is identified by the absence of Vigna sp. the absence of Haplocarpha ? hastata the absence of Scleria hispidior and the absence of Andropogon pratensis, consisting of 55 stands. The stands in this group are 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 19 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 44, 47, 48, 56, 58, 59, 62, 65, 75, 83, 87, 91, 92, 93, 94, 95, 96, 97, 98, and 99. It ranked 2^{nd} in pH, at the surface and 3^{rd} at 40 - 50 cm and 3^{rd} in average pH, 3^{rd} in conductivity, 3^{rd} in hue, 1^{st} in Chroma at the surface 2^{nd} at 30 - 40 cm but 2^{nd} in average chroma, 1^{st} in value, 3^{rd} in sodium and 2^{nd} in potassium at the surface, 3^{rd} at 30 - 40 cm and 3^{rd} in average potassium.

5.2 Environmental Data

A t-test comparing the environmental quantities of the above groups of stands (A to D) carried out in order to examine environmental similarities and differences among the groups.

Group A is distinct in consisting of stands from a marsh. The environmental factors of the other groups ie. B - D were compared using a t-test for determining significant differences in their means of scores.

In the t-test a probability of 0.05 was taken as the level of significance. The comparisons are shown in Table 9 and 10.

pH

The number of significant contrasts in the surface pH are two and the subsurface are three. In the subsurface soils groups B and D only are not contrasting significantly.

Conductivity

The number of significant contrasts in the surface soil conductivity is one and those in the subsurface are two. Only C and D contrast significantly at the surface. B and D, and C and D contrast significantly in the subsurface.

Hue

The number of significant contrasts in the surface soil hue is one and those in the subsurface are two. B and D contrast significantly in the surface, while D contrasts with C and B significantly in the subsurface.

Chroma

The significant contrasts in the surface are two, and in the subsurface 1. D contrasts with B and C significantly in the surface,

Table 9. Mean, Variance & number of observations of environmental factors.

Groups		pH		Conductivity		Hue		Chroma		Value		Sodium		Potassium		Slope
		0-10	40-50	0-10	40-50	0-10	30-40	0-10	30-40	0-10	30-40	0-10	30-40	0-10	30-40	
A	$\bar{X}$															0
	s^2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	n															5
B	$\bar{X}$	5.12	5.65	15.6	18.39	8.09	7.91	3.36	3.30	2.57	2.50	6.10	7.03	23.16	27.25	3.02
	s^2	0.17	0.23	26.54	86.17	5.55	7.32	0.29	0.27	0.73	0.82	9.94	6.91	172.23	398.46	27.69
	n	39	34	39	34	38	36	38	36	38	36	41	39	41	39	44
C	$\bar{X}$	5.41	6.00	21.11	20.99	9.28	8.5	3.75	3.80	1.71	1.60	12.04	16.38	27.96	34.51	5.71
	s^2	0.05	0.59	60.88	47.71	1.48	5.00	0.28	0.20	0.57	0.30	30.43	101.36	58.56	70.40	36.57
	n	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7
D	$\bar{X}$	5.19	5.28	14.95	14.14	7.15	5.93	3.63	3.41	2.88	2.97	4.22	4.44	22.92	23.00	271
	s^2	0.10	0.12	37.46	32.05	3.68	4.15	0.23	0.24	0.88	0.99	5.88	6.20	169.00	417.28	19.01
	n	53	47	51	47	52	48	52	48	52	48	53	49	53	49	55

Table 10. Difference Between the Means and the t Values of Environmental Factors.

	pH				Conductivity				Hue				Chroma			
	0-10		40-50		0-10		40-50		0-10		30-40		0-10		30-40	
	X_1-X_2	t	X_1-X_2	t	X_1-X_2	t	X_1-X_2	t	X_1-X_2	t	X_1-X_2	t	X_1-X_2	t	X_1-X_2	t
B & C	-0.29	2.67	-0.35	3.54	-5.43	1.77	-2.6	0.74	-0.19	0.31	-5.84	0.53	-0.20	0.91	-0.49	2.26
B & D	-0.07	0.87	0.37	3.74	0.72	0.61	4.21	2.35	0.94	2.25	1.98	3.68	-0.26	2.36	-0.10	0.92
C & D	-0.22	2.28	-0.72	2.05	-6.16	3.18	-6.84	2.13	-2.13	1.72	-2.57	2.46	-1.94	9.11	-0.39	1.83

	Value				Sodium				Potassium				Slope	
	0-10		30-40		0-10		30-40		0-10		30-40			
	X_1-X_2	t	X_1-X_2	t	X_1-X_2	t	X_1-X_2	t	X_1-X_2	t	X_1-X_2	t	X_1-X_2	t
B & C	0.86	2.68	0.90	3.12	-5.94	2.77	9.34	2.06	4.79	1.67	-7.26	1.75	-2.69	1.11
B & D	-0.30	1.61	-0.47	2.28	1.87	3.15	2.59	4.70	0.24	0.89	4.25	0.98	0.31	0.31
C & D	1.17	3.82	1.37	4.85	-7.81	3.70	11.94	2.64	5.0	1.88	-11.51	2.93	3	1.27

while only B contrasts with C significantly in the subsurface.

Value

Significant contrasts in the soil color value are 5; 2 in the surface and 3 in the subsurface.

Cations

Sodium

Significant contrasts for soil sodium are 6. The pair of all groups compared contrast significantly.

Potassium

Potassium shows little variation from group to group. Only C and D contrast significantly in the subsurface.

Slope

Group A countrasts significantly with all the pairs compared. The rest of the comparisons show no significant contrasts.

If more environmental factors had been determined meaningful comparisons at even lower levels down the classificatory bierarchy may have been attained.

Figure 1 and 2 are the dendrograms showing the classificatory hierarchy.

The vegetation types in Figure 1 are the ones considered in the comparison of the environmental data and the disscussion that followed.

The vegetation types in Figure 2 are the ultimate groups of the classification process.

The program being one that does not generate the single highest chi square, the Y axes of the dendrograms are scaled based on the highest sum of the chi squares of that particular subdivision.

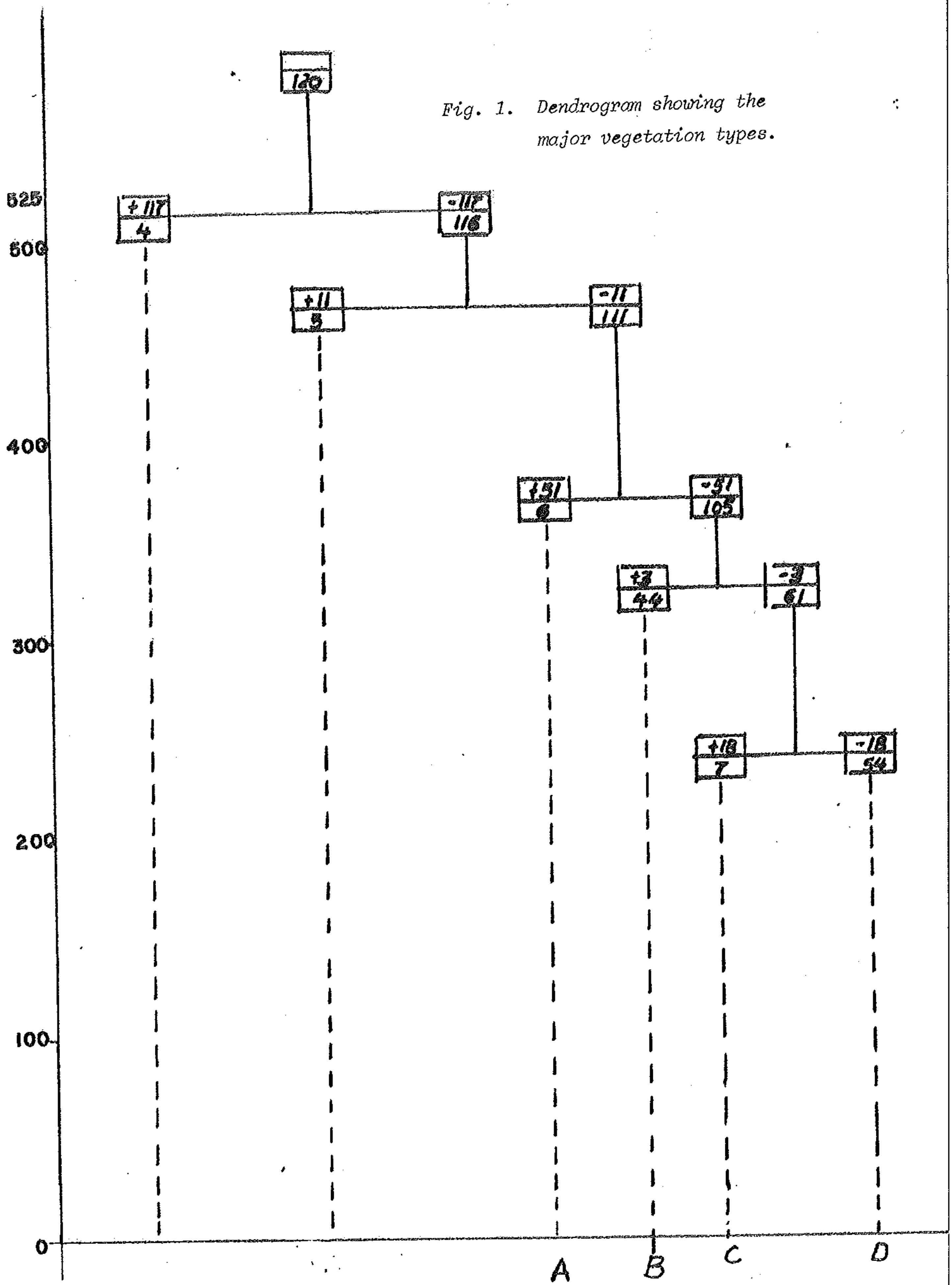

Fig. 1. Dendrogram showing the major vegetation types.

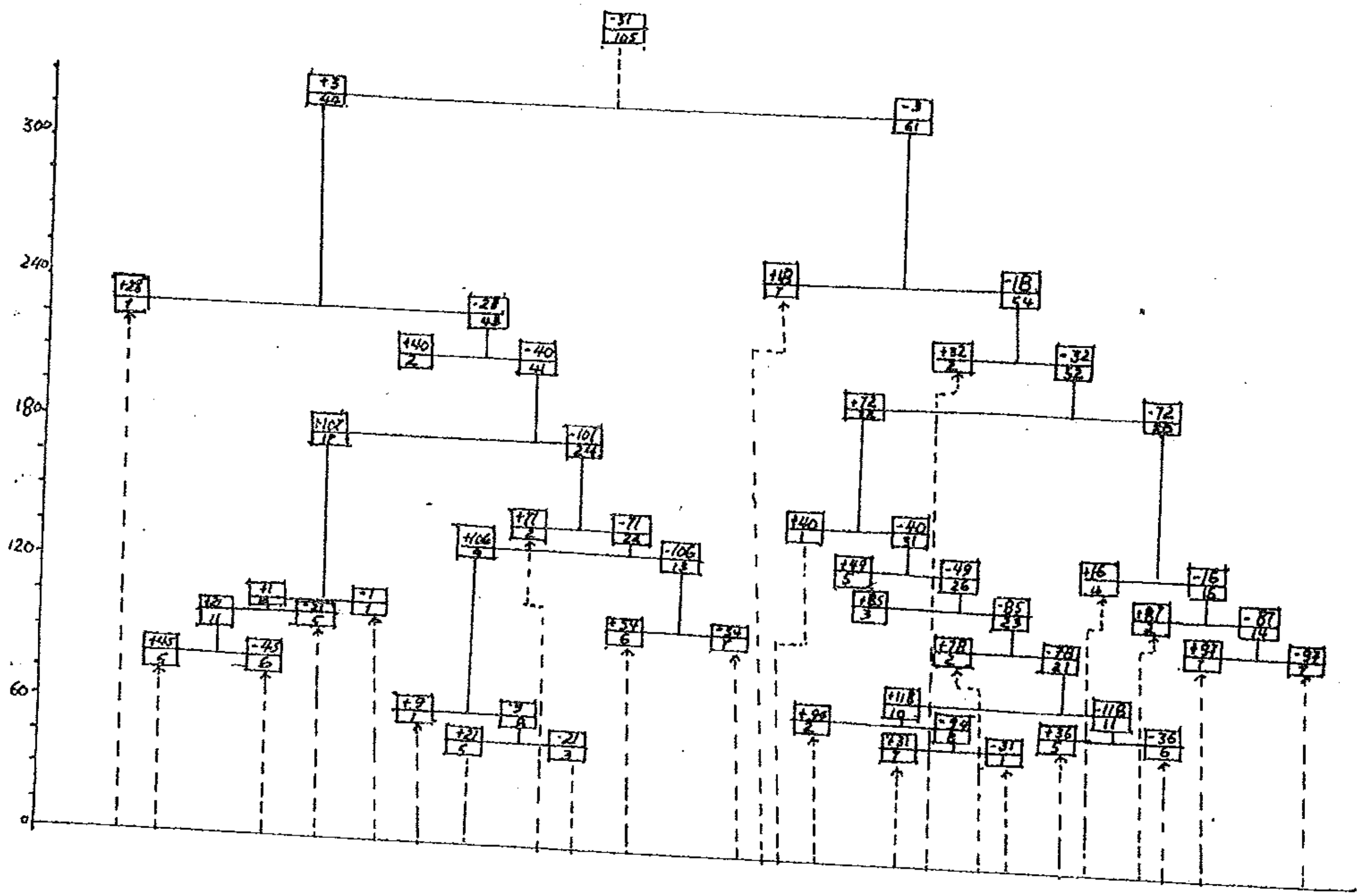

Fig 2. Dendogram showing the ultimate groups of the classification process.

6. DISCUSSION

6.1 Interaction of Environmental Factors.

Group A is the most noticeably distinct consisting of stands all in a marsh. Because of the difficulty imposed by this, no edaphic environmental factors have been quantified for it. The following discussions relating to environmental factors and vegetation will, therefore concentrate on the other groups, i.e. B, C, and D.

An arrangement of the groups based on pH gives the order C, B, D with C having the highest and D the lowest pH. According to Buckman and Brady (1969) factors which influence soil pH are the process of organic matter decomposition and leaching and the latter accounts most for the low pH values found in most soils. Bases which have been replaced from the coloidal complex or which have been dissolved by percolating acids are removed in the drainage waters. This is the normal process in the humid tropics where the rainfall is high. The annual rainfall of Addis Ababa is 1270 mm (Daniel, 1977) which is high. One can infer that the Wolmera area also recieves similar amounts of rainfall, because both areas have almost the same altitude and are near each other. In contrast to leaching any process which will encourage the maintenance or build up of exchangable bases Ca, Mg, K and Na will contribute towards a reduction of acidity and an increase in alkalimity (Young, 1976). It is therefore likely that conditions which permit the exchangable bases to remain in the soil will encourage high pH values and consequently high electrical conductivity.

The order of the groups based on conductivity is indeed identical with that based on pH. This pattern becomes repeated when the groups are arranged based on either of sodium and potassium.

An arrangement of the groups based on hue gives the order D, B, C with D having the lowest and C the highest hue. Soil color is markedly influenced by the oxidation status of iron. FeO (ferrous oxide) imparts black coloration. Red, Yellow and reddish brown colors are encouraged by well oxidized conditions. This is because as the oxidation state of iron increases, Fe_2O_3 or its hydrated form Fe_2O_3, $3H_2O$ which are red or yellow are formed (Young, 1976). Since the spaces in the soil are shared by air and water, the removal of excess quantities of the latter should take place if sufficient oxygen is to be supplied (Buckman and Brady, 1969).

Higher slope encourages drainage and hence increases aeration and promotes red coloration. As a result this could reduce the pH and the conductivity due to increased leaching. If a soil is underlain by an impermeable parent material, drainage could be impeded (Buckman and Brady,1969). One will have to agree with Buckman and Brady (1969), here that slope alone may not govern soil color and drainage. The role of parent material too, is significant. This was also suggested by Beyene (1979) in his report on the Wolmera soil colors and their relation with slope. An arrangement of the groups based on slope gives the order C, B, D, with C having the highest slope and D the lowest. The main rock types of the area are trachy basalts, poryphyr tic pyroxene basalts, aphanatic basalts, trachytes of Entoto and rhyolites

(Gezahegne, 1979). All the groups have stands on different rock types. Therefore, there seems to be no correlation between the vegetation and any parent rock material in these groups. Group A which is on trachy basalts, is marshy because it is flat and is located in a depression.

The orders of the groups based on pH, conductivity, hue (YR) and the cations are identical showing that these factors are highly correlated.

From the discussion so far, positive correlation would be expected among the factors pH, conductivity, hue and the cations which as a group would be expected to be negatively correlated with slope. The results, however, show that in this study slope is positively correlated with them.

Although soil depth per se was not taken as one of the environmental factors initially, it was later recognized that a meaningful comparison could be obtained if the augerable depths are considered as measures of soil depth.

Group B had 95% of its stands augered below 40-50 cm, D had 90% of its stands augered below 40 cm and C had only 71% of its stand augered below 40cm. An arrangement of the groups based on the percentage of the stands augered below 40 cm gives the order B, D, c with B the deepest and C the shallowest. The shallow soil depth of of group C could be attributed to the rhyolite rock out crop

(Wato Dalecha) near some of the stands in group C.

The grazing condition in the groups is such that, group D had 72% of its stands in grazed, 21% in moderately grazed and 5 in ungrazed sites. Group B had 27% of its stands in grazed, 15% of its stands in moderately grazed and 54% of its stands in ungrazed sites. The stands in group C are only moderately grazed. The arrangement of the group based on grazing then gives the order D, B, C with D the most and C the least grazed. This arrangement is the exact opposite of that based on pH, and the factors positively correlated with it.

In this study, therefore the effects of low drainage and high slope on pH and the factors correlated with it are identical.

It then seems likely that it is the hard rock near the soil surface that has discouraged the drainage and played a significant role in the increase in pH, conductivity and hue of group C. The soil depth could also be a factor for the reduced grazing, since only those plants which can tolerate impeded drainage and shallow soils could establish themselves in such environments because palatable and high yielding plants are high in their nutrient demands.

All the stands in group C were moderately grazed, but not fenced or protected. In the other groups the ungrazed stands were in protected sites, which would presumably have been grazed as well as the unprotected stands in the same groups. Group A was ungrazed because the marsh discourages grazing animals and minimizes interference. Besides the sedges in the marsh are unpalatable.

The interaction of the environmental factors suggest that as drainage decreases, pH, conductivity, the cations and hue (YR) increase, while grazing decreases. Gentle slope and shallow soil depth decrease drainage. Shallow soils irrespective of their slope having impeded drainage and marshes are not well grazed.

7. SUMMARY WITH SUGGESTIONS FOR MANAGEMENT OF THE GRASSLAND

The objective of grassland management is to maintain pastures at the best stage for grazing, which not only provides a dense cover on the soil, but also the optimum productivity of the most nutritious grasses for any given soil and climatic conditions.

Plant species in general change to meet varying conditions of soil, climate and the use made by man and his livestock. For these reasons, it is not feasible to attempt generalizations that could apply nationwide.

The efficient utilization of grasslands and the discovery and application of new facts relating to their improvement are vastly more complicated than any single crop. For grasslands, a wide range of plant species is involved, each with its own characteristics and these occur in mixtures rather than as single species.

In this study, it is found that the grassland plants also prefer the arable areas which are favorable for most cereals and pulses. Areas abandoned because of water logging or totally uncultivated as a result of this are also the ones rejected by grazers. Grasslands also have to be well drained, possess deep soils so that nutritive and productive grassland plants can establish successfully.

This seems paradoxical in that part of the arable plots of land where a farmer could grow food or cash crop is to be occupied by grasses. But if the grasslands are well managed, cattle and other domestic animals could be competitive with cereals in the value of their produce.

Some land now tilled might better be restored to permanent grassland, particularily in Bedi, where crops are too uncertain in performance. The closeness of this region to Addis Ababa makes it a profitable place for a dairy farm.

Marshes occupy a considerable area of the land in Wolmera. Two alternative ways of utilizing this wasted area are either draining the marshes or the introduction and establishment of forage species suited to these conditions.

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