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SIGNY ISLAND:

A CASE STUDY OF ECOLOGICAL CHARACTERISATION

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Introduction

Signy Island belongs to the South Orkney Islands (60°S, 45°W) within the maritime Antarctic region (Holdgate, 1967). The north point of the island is only 1.5 km distant from Coronation Island, largest of the South Orkney group. The tip of the Antarctic peninsula lies some 640 km to the west; the nearest subantarctic and temperate lands are South Georgia, some 900 km north east and Tierra del Fuego, about 1440 km north west. There has probably been some immigration of plants and animals from all these regions, but especially from the sub-polar zones in the period since the last glacial maximum.

The climate of the island is substantially cooler than that of South Georgia (annual mean temperature -3.8C), but the oceanic influence is reflected in the relatively narrow range of annual temperatures, and in the considerable rainfall, high relative humidity and cloudiness. The highest summit reaches 280 m, and the topography is rugged. There is a small ice cap in the south of the island, with two main glacier outlets, one to the south and one to the east. There are numerous small freshwater lakes The vegetation is generally sparse, but there are extensive stands of bryophytes on the more stable knolls and slopes at low altitudes: the associations are typical of the maritime Antarctic zone (Longton, 1967).

A British scientific station was established on the island in 1947, and a biological laboratory complex was installed in 1964. Studies of several well-defined habitats and communities have produced a considerable quantity of inter-related data and, since 1970, much of the long-term sampling has been concentrated on two specific sites where a long-term programme of microclimate monitoring has been established.

The vegetation of Signy Island was mapped by Holdgate in 1961-64, and a phyto-sociological analysis of the plant associations has been published by Smith (1972). These surveys were, however, based on visual inspection of the island rather than on a deliberate characterization and stratification. The most recent summary account of the island and its ecology is by Collins et al (1975), who list many references and describe productivity studies undertaken in the International Biological Programme, but even this description does not give any integrated picture of the relationships between the various environmental and vegetation types.

In the preparation of a review paper for a recent Royal Society Discussion (Holdgate, in press), an attempt was made to examine more systematically the variability in the topography and vegetation of Signy Island and see how far these could be related. The present paper presents a fuller analysis and characterization of the environment and vegetation of Signy Island, based on data extracted from published and unpublished maps. The methods of analysis have been developed during research on ecological characterization carried out within ITE and are described with only sufficient detail to make the characterization intelligible. Discussion of the basic mathematics and of the mathematical assumptions has already been presented in other papers, for example in Jeffers 1969a and 1969b.

Basic data

An arbitrary grid of 500 m^2 squares was imposed on the 1:25,000 scale map of Signy Island, giving 104 squares containing appreciable areas of land. For the environmental variables, each of the 22 variables summarised in Table 1 was assessed for each square, the geological details being derived from the sketch map by Matthews and Maling (1967). Similarly, the percentages of the total area of rock and of drift and scree (the only areas capable of being colonized by plants) occupied by each of 13 vegetation types, summarised in Table 2, were assessed for each of the squares from an unpublished map drawn by Holdgate in 1961/62 and 1963/64.

Table 1. Summary of environmental variables for Signy data

Variable	Minimum	Mean	Maximum	Standard Deviation
1. Minimum altitude	0	30.2	230	52.1
2. Maximum altitude	5	140.0	280	79.3
3. Contours cut on N-S transect	0	7.0	21	5.35
4. Contours cut on E-W transect	0	7.5	22	5.44
5. Percentage slope facing N	0	15.4	90	18.3
6. Percentage slope facing E	0	17.5	90	23.0
7. Percentage slope facing S	0	19.2	100	25.0
8. Percentage slope facing W	0	20.8	90	24.3
9. Percentage occupied by sea	0	26.6	95	32.3
10. Percentage occupied by lakes	0	1.2	20	3.47
11. Percentage occupied by permanent ice and snow	0	31.8	100	35.3
12. Percentage shown as rock	0	13.3	45	9.12
13. Percentage shown as drift or scree	0	27.2	91	25.8
14. Distance to sea to N	0	1523	6000	1736
15. Distance to sea to E	0	1026	4100	1084
16. Distance to sea to S	0	1728	6100	1855
17. Distance to sea to W	0	1004	4250	1114
18. Length of streams in square	0	137.5	1300	235.6
19. Length of coastline in square	0	469.1	1950	503.1
20. Percentage of quartz-mica-schist	0	9.1	35	6.93
21. Percentage of amphibolites	0	3.4	25	4.48
22. Percentage of marbles	0	0.86	5	1.40

Table 2. **Summary of modified vegetation variables for Signy data**

Variable			Min	Mean	Max	S.D.
1.	Moss carpet	Continuous	0	2.54	30	4.56
2.	Moss carpet	Discontinuous	0	1.70	22.5	4.07
3.	Moss turf	Continuous	0	1.90	17	3.16
4.	Moss turf	Discontinuous	0	0.03	1.4	0.16
5.	Lichen moss	Continuous	0	6.49	31.2	7.11
6.	Lichen moss	Discontinuous	0	18.5	85	18.7
7.	Basic communities		0	0.40	14	1.88
8.	Areas modified by birds and seals		0	2.62	40	6.25
9.	Mosaics - carpet turf	Continuous	0	0.27	7.3	1.11
10.	Mosaics - carpet/lichen and moss	Continuous	0	1.17	15	2.39
11.		Discontinuous	0	3.09	22.5	5.03
12.	Mosaics - turf/lichen and moss	Continuous	0	1.53	10.1	2.17
13.		Discontinuous	0	0.15	2.7	0.51

These data sources could undoubtedly be improved, and the derivation of measurements from them given greater precision, but the present study was intended to be illustrative and exploratory rather than definitive. Its aim is to examine how far a relatively quick scrutiny of maps can yield information about habitat variability and the inter-relationships of the component variables in a manner that may usefull stratify field surveys and how far the pattern of subjectively-mapped vegetation on Signy Island could be related to the environmental analysis. The variables scored from the maps were simply those conveniently determinable.

Analysis of environmental variables

The coefficients of the correlations between the 22 environmental variables are given in Table 3. As is usual for sets of variables of this kind, the number of intercorrelations between the variables is large. The interpretation of correlations is necessarily complex and is provided by the subsequent analysis, but some observations on the correlation coefficients themselves are worth noting.

The highest correlation is between the percentage of rock and the percentage of quartz-mica-schist, with the percentage of rock also being strongly correlated with the percentage of amphibolites. A second cluster of highly correlated variables contains the two measures of altitude, the two counts of numbers of contours, the percentage slope facing S, the percentage occupied by sea, the percentage occupied by snow and ice, the distance to sea to N, and the length of coastline, some of these correlations being negative. The two groups are connected by the negative correlation between the percentage of rock and the percentage of snow and ice, and the positive correlation between the contours cut on the N-S transect and the percentage of amphibolites.

A third group of correlated variables includes the percentage slope facing W, the percentage of drift and scree, and the length of streams, with the percentage of drift and scree negatively correlated with the percentage occupied by snow and ice and the percentage slope facing W negatively correlated with the percentage occupied by sea.

The first seven eigenvalues of the correlation matrix of the environmental variables are summarised in Table 4. The seven components represented by these eigenvalues account for 77.5 per cent of the total variability described by 22 variables, with the first three of the components accounting for 53.3 per cent of this variability. There are, therefore, at least seven independent axes of variation described by the variables, and the interpretation of these axes is facilitated by the eigenvectors given in Table 5.

The first component, accounting for 23.2 per cent of the total variability, is primarily a measure of altitude and of the associated features of sea and coast and permanent snow and ice. It corresponds to the major group of correlated variables noted above. The second component is an index of the percentage of slopes facing W, the percentage of drift and scree, and the length of streams, and accounts for a further 18.8 per cent of the total variation. It may perhaps be regarded as an index of available habitats for vegetation. The third component, accounting for a further 11.3 per cent, is a measure of the percentage of rock and of quartz-mica-schist.

The remaining components are mainly topographical in nature. The fourth component (8.2 per cent) gives greatest weight to the distance to the sea to the E, the fifth component (6.1 per cent) is a contrast between the percentage occupied by lakes and the percentage slope facing N, the sixth component (5.4 per cent) gives greatest weight to the percentage of slope facing S, and the seventh component (4.5 per cent) is a contrast between the number of contours cut on E-W transects with the percentage of marbles and minimum altitude.

From the eigenvectors of Table 5, it is possible to calculate the component scores of the 104 map squares which may be used to plot the position of each square in the reduced dimensions represented by these seven orthogonal axes. The component scores are summarised in Table 6, and are plotted as contour maps in Figure 1, where the following symbols have been used.

Table 3 Coefficients of correlations between environmental variables

1															
.655***	2														
.039	.561***	3													
-.025	.587***	.593***	4												
.073	.283**	.375***	.203*	5											
.125	.324***	.172	.359***	-.132	6										
.311**	.212*	.204*	-.095	-.322***	-.093	7									
.147	.271**	.133	.285**	.071	-.292**	-.201*	8								
-.481***	-.750***	-.558***	-.487***	-.289**	-.311*	-.353***	-.434***	9							
-.105	-.065	.030	.123	-.049	.176	-.018	.036	-.215*	10						
.709***	.699***	.235*	.164	-.038	-.358***	.514***	-.012	-.620***	-.046	11					
-.274**	-.044	.346***	.239*	.199*	.043	-.172	.067	-.025	.092	-.383***	12				
-.256**	.007	.254**	.285**	.351***	-.142	-.196	.534***	-.368***	.165	-.454***	.191	13			
.424***	.465***	.185	.169	-.192	.366***	.505***	-.156	-.378***	-.097	.715***	-.244*	-.409***	14		
.142	.184	.183	.031	.197*	-.303**	.016	.322***	-.170	.029	.071	.120	.069	-.034	15	
.099	.213*	.077	.150	.184	-.057	-.233*	.390***	-.198*	.069	-.070	-.069	.362***	-.231**	.095	16
.100	.121	.085	.057	-.098	.327***	.296**	-.328***	-.171	-.019	.323***	-.133	-.181	.260**	-.412***	-.368***
-.153	.055	.035	.221*	.186	-.168	-.208**	.588***	-.256**	.205*	-.173	.042	.515***	-.213	.145	.284**
-.545***	-.727***	-.307**	-.373***	-.189	-.223*	-.258**	-.340***	.759***	-.175	-.617***	.204*	-.157	-.341***	-.202*	-.246*
-.298**	-.203*	.189	.077	.118	-.026	-.179	-.074	.152	-.041	-.452***	.847***	.136	-.380***	-.040	-.114
-.028	.237*	.415***	.320***	.181	.113	-.029	.209*	-.242*	.133	-.012	.622***	.081	.145	.326***	-.032
-.167	-.019	-.014	.137	.109	.110	-.166	.131	-.150	.360***	-.178	.325***	.271	-.145	-.097	.232*

17					
-.223*	18				
-.059	-.179	19			
.003	-.031	.362***	20		
-.273**	.125	-.130	.144	21	
.012	.239*	-.064	.113	.171	22

P0.05 = .194

P0.01 = .254

P0.001 = .318

Table 4 Eigenvalues of environmental correlation matrix

Component	Eigenvalue	Proportion of total variability Component	Cumulative
I	5.10	.232	.232
II	4.15	.188	.420
III	2.48	.113	.533
IV	1.81	.082	.615
V	1.34	.061	.676
VI	1.18	.054	.730
VII	1.00	.045	.775

Table 5 Eigenvectors of the environmental variables

Variable Number	Eigenvector for component:-						
	I	II	III	IV	V	VI	VII
1	.7424	.3615	.3386	.3130	.1214	.2705	.8890
2	1.0000	-.1616	-.0787	.1356	.3393	.2460	.0404
3	.5826	-.5205	-.6298	.2851	.3411	-.3403	-.3411
4	.5560	-.5951	-.4707	-.2778	.2494	.1376	-1.0000
5	.1892	- 6427	-.0493	.2448	.8535	.1854	.7618
6	.4112	.2131	-.6784	-.7528	-.0028	.7297	-.3701
7	.4574	.5952	-.1228	.2749	-.4439	-1.0000	.3234
8	.2882	- 8270	.6517	.1104	-.1555	-.2427	-.4309
9	-.9628	3950	.0382	.1969	.0181	.3701	-.2752
10	.0762	- 3236	-.0872	-.7183	-1.0000	-.0179	.5154
11	.9277	5895	.0524	.0762	-.0613	.1037	1705
12	-.1979	-.7432	-1.0000	.3838	-.2276	.0164	.4115
13	-.0040	-1.0000	.2469	-.3915	.2786	-.6153	-.0978
14	.6956	.6440	-.2466	.1133	-.3580	.0461	- 5518
15	.2014	-.4234	.3306	1.0000	-.4720	.0763	.1528
16	.1445	-.6160	.6375	-.2636	.2530	.4881	.4380
17	.2278	5797	-.5384	-.6542	.4285	-.6141	.2317
18	0.756	-.8140	.5140	-.3432	-.1948	-.2906	-.6275
19	-.9106	.1830	-.3063	.1587	.0758	-.0074	-.3179
20	-.4116	-.4698	-.9004	.2816	.2762	-.2062	.5732
21	.2522	-.6026	-.5877	.5782	-.7170	.3397	-.3371
22	-.0285	-.5493	-.2044	-.7564	-.5458	.1445	.9390

Table 6 Summary of component values

Component		Min	Mean	Max	Standard deviation
I	Maximum altitude and ice/snow versus percent sea and length of coast	-4.27	0.00	3.60	2.26
II	% slope W and drift/scree	-4.63	0.00	4.02	2.04
III	% rock and quartz-mica-schist	-4.76	0.00	3.20	1.58
IV	Distance to sea to E	-3.94	0.00	3.61	1.35
V	% slope N versus % lake	-3.61	0.00	3.03	1.16
VI	% slope S	-3.16	0.00	2.44	1.09
VII	Minimum altitude versus contours cut E-W	-2.83	0.00	2.94	1.00

P	Symbol
1	=
2, 3	-
4, 5, 6	.
7, 8	+
9, 10	#

where P = INT $(6 + Z_i)$, and Z_i is the value of the ith component

The map of the first component clearly shows the changes in altitude, with the high values in the centre and south of the island, and low values at the coast. The second component shows the western slopes and drift/scree areas to the west of the island, with the high values representing absence of these characteristics to the east and south. In the map of the third component, the areas with high percentages of rock and quartz-mica-schist are shown as negative, with the positive values representing relative absence of these properties.

The map for the fourth component shows clearly that, although only the distance from the sea to the east has a high weighting in the eigenvectors, the component is relatively complex, with the positive values grouped to the SW of the island and a small group of negative values to the NE. Component five shows the N slopes as positive values and the presence of lakes as negative values. Component six is complex, with the positive values showing the relative absence of S slopes, and component seven is also complex, with the positive values showing relatively high minimum altitudes and high percentages of marbles.

A cluster analysis was carried out on the 104 component values, using a modification of the minimum spanning tree technique. The resulting clusters are summarised in Table 7. The 104 squares cluster into ten primary clusters, most of which are composed of two or more secondary clusters. Three of the primary clusters (i.e. clusters 8, 9 and 10), however, are essentially outliers to the main group of squares.

The projection of the clusters on the plane of the first and second component is given in Figure 2. Clearly, on this projection, only the seventh cluster is easily discriminated. The projections of the clusters on planes of the other components can be similarly plotted, but few of the clusters are likely to be clearly discriminated by projections on the plane of any two axes, for variation which is mapped in seven dimensions of multivariate space.

Table 7 Cluster analysis by environmental components

Primary cluster	Secondary cluster	Square number
1	1	1 2 49
	4	5 9
	5	6 36 23 17 11 24 29
	2	3 7
	28	72
2	3	4
	12	26 40
	10	19 25 33
	11	20 27
3	6	8 18
	8	12 13 69 59
4	7	10 16 22
	13	28 35 42 62 98 91 43
5	9	14 100 101 15 21 34 51 50 99 41
	29	79 89 90
	23	52 80 92 71
	26	60 61 78
	27	70
	30	87 96 88 97 104
6	14	30 82
	20	45 73 64
	18	83 38
	15	31
	19	44 81 54 93 102
7	16	32 66 47 39 55
	21	46 65 56
	22	48 58 68 84 74 95
	25	57 67 75 85 76 77 86 94
8	17	37
9	24	53 63
10	31	103

The geographic distribution of the clusters is plotted in Figures 6 and 7, and these figures further illustrate the nature of the clusters derived from the analysis of the environmental variables. Clusters 4, 5, 9 and 10 are mainly composed of coastal squares, while clusters 2, 3 and 7 are mainly composed of inland squares. Cluster 1 is largely confined to the north of the island, while cluster 7 represents high elevations with snow and ice.

Discussion of environmental variables

The analysis of the 22 basic environmental variables suggests that these variables define a total variability of which approximately 78 per cent is accounted for by seven orthogonal dimensions. This is a surprisingly large number of dimensions for data derived from maps, and indicates some marked insight in the choice of the original variables. Nevertheless, there is considerable redundancy in the data, and a reduced set of variables can be defined as accounting for a large part of the total variability. One possible set of variables is listed in Table 8, together with the coefficients of the correlations between the variables of this reduced set.

Further analysis of environmental data should therefore be concentrated on alternative variables which are correlated as little as possible with those of the reduced set of Table 8. This further analysis might be done, for example, by adding new variables derived from the same or different maps and surveys to these seven and by repeating the principal component analysis. If the dimensionality is thereby increased, it may be confidently assumed that the new variables have been successful in extending the variability described, and a new reduced set of variables can then be selected. In this way, further research can be related to a parsimonious set of variables which can be modified and improved iteratively.

The cluster analysis based on the environmental components defines some major clusters of squares, with three outliers. Each of these clusters may be discriminated by the component scores (Table 9), or by values of the reduced set of variables (Table 10). Broadly, the clusters identify coastal and inland environments, with a separate cluster for squares with high maximum altitudes and high percentages of ice and snow. It is of some interest to speculate on the value of the clusters in characterizing the environments, at least on the scale set by the choice of the grid size, and the relevance of the characterization to the distribution of vegetation is discussed below.

The outliers are readily identified. Cluster 8, for example, consists of an isolated square with 15 per cent of its area occupied by lakes. Cluster 9 consists of two squares on the west of the island with high percentages of rock, and cluster 10 is an isolated square at the far south of the island which includes Point Confusion.

Table 8. Reduced set of environmental variables

Original number	Variable
2	Maximum elevation
4	Contours cut on E-W transect
7	Percentage slope facing S
10	Percentage occupied by lakes
12	Percentage shown as rock
13	Percentage shown as drift and scree
15	Distance of sea to E

Correlation coefficients

2						
.587***	4					
.212*	-.095	7				
-.065	.123	-.018	10			
-.044	.239*	-.172	.092	12		
.007	.285**	-.196*	.165	.191	13	
.184	.031	.016	.029	.120	.069	15

Table 9. Average component scores for environmental clusters

Cluster	No. of squares	Average score for component:- I	II	III	IV	V	VI	VII
1	15	-0.94	-1.71	1.75	-0.40	0.16	0.07	-0.50
2	8	0.68	-1.53	-1.32	-2.43	-0.80	0.63	0.90
3	6	1.24	-0.87	0.88	-1.04	0.60	-0.89	0.17
4	10	-3.18	1.46	1.56	0.36	-0.01	0.80	-0.17
5	26	-1.90	0.71	-1.05	0.00	0.27	-0.61	0.04
6	13	1.48	-2.02	-0.39	1.25	-0.38	-0.07	0.01
7	22	2.80	2.12	0.25	0.24	0.17	0.29	0.06
8	1	1.21	-2.79	0.98	-1.97	-3.61	1.25	0.38
9	2	-0.34	-3.31	-2.87	3.45	0.21	-0.50	0.61
10	1	1.31	-1.08	-4.76	1.64	-1.99	1.35	-2.83

Table 10. Average values of variables for environmental clusters

Cluster	No. of squares	Average value for variable Max. alt.	E-W contours	S slope	% lakes	% rock	% drift & scree	Sea to E
1	15	114	7	2	1	10	52	1090
2	8	150	11	9	8	19	44	306
3	6	185	11	30	2	9	61	467
4	10	37	1	3	0	5	5	1145
5	26	80	5	18	0	17	23	525
6	13	193	12	21	2	20	37	2035
7	22	224	8	38	0	6	3	1148
8	1	150	8	0	15	15	30	1500
9	2	185	10	23	0	40	38	3325
10	1	140	18	45	0	35	25	200

Analysis of vegetation data

The coefficients of the correlations between the 13 vegetation variables are given in Table 11. These coefficients suggest a group of closely and significantly correlated variables which includes continuous moss carpets, continuous moss turf, continuous and discontinuous mosaics of carpet/lichen and moss and continuous mosaics of turf/lichen and moss. The remaining variables are loosely correlated with one or more variables of this central group. Thus, discontinuous moss carpet is significantly correlated with continuous moss carpet, and basic communities significantly correlated with both of these variables. Similarly, mosaics of carpet turf are significantly correlated with continuous moss turf and with mosaics of turf/lichen and moss, continuous lichen moss with continuous mosaics of carpet turf and of turf/lichen and moss, discontinuous lichen moss with continuous lichen moss, and areas modified by birds and seals negatively correlated with discontinuous lichen moss. Discontinuous mosaics of turf/lichen and moss are significantly correlated with continuous moss carpet, discontinuous mosaics of carpet/lichen and moss and continuous mosaics of turf/lichen and moss, while discontinuous moss turf is correlated with continuous and discontinuous mosaics of turf/lichen and moss.

The eigenvalues of the principal components of the correlation matrix are summarised in Table 12, together with the proportions of the total variability accounted for by each component. The first five components together account for 70 per cent of the total variability, and the first seven principal components for 82.1 per cent. The eigenvalues for each of these first seven components are given in Table 13.

The first component, accounting for 26.2 per cent of the total variability, is a general index of the presence of vegetation, with greatest weight given to continuous moss carpet and moss turf, discontinuous mosaics of carpet/lichen and moss, and continuous mosaics of turf/lichen and moss. The second component, accounting for a further 13.7 per cent, is a contrast between continuous lichen moss and areas modified by birds and seals. The third component (11.2 per cent) is mainly a contrast between discontinuous lichen moss and turf/lichen and moss and continuous mosaics of carpet/turf. The fourth component (9.8 per cent) is a contrast between basic communities, continuous lichen moss, continuous mosaics of carpet/turf and discontinuous mosaics of carpet/turf. The remaining components, accounting for 9.1 per cent, 6.3 per cent, and 5.8 per cent, are mainly measures of the amounts of discontinuous moss turf, areas modified by birds and seals, and continuous mosaics of carpet/lichen and moss.

The computed values of these seven components for each of the 104 map squares define the position of each square in seven-dimensional orthogonal space, and the component values are summarised in Table 14.

The interpretation of the components is helped by the plotting of contour maps of the component values in Figure 5, where the following symbols have been used.

Table 11 **Coefficients of correlations between vegetation variables**

1												
.369***	2											
.511***	.016	3										
.003	.047	.113	4									
.086	.057	.308	.285	5								
-.027	.082	-.020	-.025	.352***	6							
.255**	.372***	.132	-.033	.059	-.065	7						
.121	.198*	-.011	.010	-.158	-.228*	.109	8					
.239*	-.011	.419***	-.003	.214*	-.135	-.052	-.004	9				
.568***	.062	.413***	-.067	.036	.049	-.026	.096	-.030	10			
.638***	.194*	.530***	-.001	.060	.138	.103	.138	.087	.377	11		
.479***	.045	.586***	.218*	.385***	.157	-.048	-.051	.339***	.352***	.500***	12	
.266**	.095	.114	.304**	-.043	.167	.097	.078	-.074	.190	.375***	.235*	13

* P0.05 = 0.194
** P0.01 = 0.254
*** P0.001= 0.318

Table 12. Eigenvalues for vegetation variables

Component	Eigenvalue	Proportion of total variability: Component	Proportion of total variability: Cumulative
I	3.41	0.262	.262
II	1.78	0.137	.399
III	1.46	0.112	.511
IV	1.27	0.098	.609
V	1.18	0.091	.700
VI	0.82	0.063	.763
VII	0.75	0.058	.821

Table 13 Eigenvectors for vegetation variables

Variable	Eigenvector corresponding to component: I	II	III	IV	V	VI	VII
1	1.0000	.5046	.1695	.0133	.1676	.0929	.1512
2	.3460	.8327	-.6057	-.7505	.2894	-.3004	-.0751
3	.9450	-.3301	.4655	-.1917	.0162	.1755	.2129
4	.2225	-.4454	-.6374	-.4107	-1.0000	-.0148	.5859
5	.4259	-1.0000	-.4712	-.7128	.1962	-.4333	.3374
6	.1752	-.5828	-1.0000	.4205	.6054	-.3120	-.6169
7	.2432	.7733	-.3606	-1.0000	.2947	.6267	.2248
8	.1198	.9324	.2226	-.2310	-.4848	-1.0000	-.4215
9	.4164	-.5844	.8628	-.7024	-.0826	.0766	-.8734
10	.7296	.2813	.2173	.7997	.1849	-.2825	1.0000
11	.9382	.3133	-.0405	.4324	.0452	.0844	-.5173
12	.9351	-.5820	-.0676	-.0499	-.1057	-.0940	-.0833
13	.4968	.2717	-.7327	.5563	-.6196	.4795	-.6021

P	Symbol
1	=
2, 3, 4	-
5	.
6, 7, 8	+
9, 10	#

where P = INT (6 + X(I))

Table 14. **Summary of vegetation component values**

Component	Min	Mean	Max	S.D.
I	-1.70	0.00	5.87	1.85
II	-3.20	0.00	4.52	1.33
III	-4.33	0.00	4.64	1.21
IV	-4.49	0.00	3.69	1.13
V	-7.30	0.00	2.14	1.09
VI	-3.72	0.00	2.71	0.90
VII	-2.59	0.00	3.32	0.87

The first component shows the presence of vegetation to be largely confined to the coasts and edges of the island, while the second component provides a further subdivision of this coastal vegetation, high values of this second component indicating the presence of birds and seals. Most of the remaining components also give further subdivisions of the vegetation of the coastal strip, yielding a relatively complex mosaic of vegetation types.

A cluster analysis was performed on the 104 component values, again using a modification of the minimum spanning tree technique. The resulting clusters are summarised in Table 15. The 104 squares cluster into seven primary groups. One of these groups contains 88 of the squares, but is itself composed of six sub-groups of approximately equivalent status to the remaining groups. Two of the main 'groups' are essentially outliers to the main classification.

The geographical distribution of the seven vegetation clusters is plotted in Figures 6 and 7, from which the peripheral nature of all clusters except the first is evident. Thus, cluster 2 is confined to the western coast of the island, cluster 3 to the west and inland, cluster 4 to the east and inland, cluster 5 to the north-west and inland, while clusters 6 and 7 are outliers of the east coast and south-west respectively.

Table 15 Cluster analysis by vegetation components

Group	Subgroups	Squares
1	A	1 100 90 101
	B	2 16 29 49 36 10 43 28 62 22 87 91 35 77 42 97 46 68 48 47 57 58 67 75 85 86 56 96 65 66 76 95 98
	C	5 9 39 32 84 45 104
	D	8 19 21 15 81 72 41 33 74 38 55 37 73 103 40 13 25 31 64 52 94 12 63 93 83 69 18 82
	E	11 59 30 24 44 60 61 80 26 70
	F	51 92 78 71 79 89
2		3 6 53 7 102 23
3		4 17 54
4		14 99
5		20 27 34
6		50
7		88

The geographical distribution of the six sub-groups of the first vegetation clusters is plotted in Figures 8 and 9, and suggests that these sub-groups are less clearly localized than the main vegetation clusters. Nevertheless, sub-group 1 is confined to the north and south-east coasts and the sub-group 6 to the south of the island. The remaining sub-groups form mainly contiguous, but less readily identified, areas.

Discussion of vegetation variables

The 13 variables describing the percentages occupied by the vegetation of Signy Island contain less redundant information than the environmental variables, seven orthogonal dimensions accounting for 82.1 per cent and five orthogonal dimensions accounting for 70 per cent of the total variability described by the variables. The various components describe combinations of the continuous and discontinuous turfs and carpets of lichen and moss which suggest a relatively complex interaction with environmental factors. The first of these components is a general index of the presence of vegetation, while the remainder of the components indicate various subdivisions and modifications of the vegetation.

The cluster analysis of the vegetation component scores identifies the major part of the island where the vegetation is generally relatively sparse, the sub-groups of this first cluster being of approximately the same order as the major classification of the less sparse vegetation. The major areas of vegetation are clearly identified as being confined to the coasts and edges of the island, with distinct areas modified by birds and seals. The average component scores for the six sub-groups of the first cluster and the remaining six clusters are given in Table 16.

Relationships between vegetation and environmental variables

The correlations between the vegetation and environmental components are summarised in Table 17.

The fourth, fifth and sixth vegetation components are significantly positively correlated with altitude, while the general presence of vegetation (Vegetation component I) is significantly negatively correlated with altitude. Similarly, the general index of vegetation and vegetation components V and VI are positively correlated with W slopes and the percentage of drift and scree, while vegetation components III and VI are negatively correlated with these variables. The remaining environmental components show fewer correlations with vegetation components.

The cross-classification of the individual squares by environmental and vegetation clusters is given in Table 18. Clearly, the classification is dominated by the 88 squares of the first vegetation cluster, and these squares are not concentrated on any of the environmental clusters. Similarly, none of the remaining vegetation clusters is strongly associated with the environmental clusters. The vegetation clusters are therefore not strongly correlated with the environmental clusters.

The cross-classification of the squares by the sub-groups of the first vegetation cluster and the environmental clusters is given in Table 19. Again, the vegetation sub-groups are not strongly correlated with the environmental clusters.

The presence of vascular plants was recorded for 22 of the squares, and the location of these squares is plotted in Figure 10, with the vascular plants distributed along the NE and NW coasts of the island.

Table 16. Average component scores for vegetation clusters

Cluster		No. of squares	I	II	III	IV	V	VI	VII
			Average score for component:-						
1	A	4	-1.0	2.4	1.0	-0.3	-1.7	-2.5	-1.0
	B	33	-1.2	0.3	0.5	0.3	-0.4	0.4	0.2
	C	7	-1.4	0.0	0.3	0.2	-0.1	0.4	0.0
	D	28	-0.8	-0.3	-0.6	0.0	0.6	-0.2	-0.1
	E	10	0.8	-1.7	-0.6	-0.2	0.8	-0.7	0.4
	F	6	1.3	-1.6	1.8	-1.3	-0.1	-0.1	-0.9
2		6	4.1	1.6	1.1	0.8	0.9	-0.2	2.0
3		3	3.5	0.7	-2.1	2.9	-0.9	1.1	-2.1
4		2	0.4	-1.0	-1.6	-2.0	-2.2	-0.8	1.2
5		3	1.5	3.6	-2.0	-3.0	0.7	1.3	-0.3
6		1	3.7	-3.2	-4.3	-1.3	-7.3	0.6	1.7
7		1	5.9	-2.5	4.6	-2.5	-0.1	1.2	-2.5

Table 17 Coefficients of correlations between environmental and vegetation components

Environmental component	Vegetation component:- I	II	III	IV	V	VI	VII
I	-.220*	-.139	-.154	.270**	.235*	.198*	-.078
II	-.604***	.056	.420***	-.229*	-.307**	.263**	.084
III	.073	.221*	.057	.170	.015	.186	.047
IV	-.108	-.245*	.089	.297**	-.023	.000	.090
V	.033	-.247*	.081	.041	-.158	-.115	.000
VI	-.322***	.106	-.030	.197*	-.025	.036	.172
VII	-.135	.058	-.094	-.280**	.037	.000	-.133

P (0.05) = .194

P (0.01) = .254

P (0.001)= .318

Table 18 Cross classification of squares by environmental and vegetation clusters

Environmental clusters	Numbers of squares in veg cluster: 1	2	3	4	5	6	7	Totals
1	10	4	1					15
2	5		1		2			8
3	6							6
4	10							10
5	21			2	1	1	1	26
6	11	1	1					13
7	22							22
8	1							1
9	1	1						2
10	1							1
Totals	88	6	3	2	3	1	1	104

Table 19 [redacted]s classification of the squares by the sub-groups of the first vegetation cluster and the environmental clusters

Environmental Clusters	Numbers of squares in sub-group: 1	2	3	4	5	6	Totals
1	1	4	2	1	2		10
2				4	1		5
3				5	1		6
4		10					10
5	3	3	1	4	4	6	21
6			1	8	2		11
7		16	3	3			22
8				1			1
9				1			1
10				1			1
Totals	4	33	7	28	10	6	88

Three types of predictors can be derived from the analyses carried out on the environmental and vegetation data. First, it is possible to predict values of the vegetation components from the observed values of the environmental components. Second, it is possible to predict the values of individual vegetation variables from the values of selected environmental variables. Third, it is possible to predict the presence of vascular plants from either the environmental variables or the vegetation variables. The last type of prediction can also be expressed as discriminant functions for the presence of vascular plants. Each of these types of predictions are illustrated below.

Table 20 summarises the significant relationships between the vegetation and environmental components. For all vegetation components except the seventh, the environmental components provided significant predictors. The proportions of the total variability accounted for, however, were low, and below 20 per cent for all components except the first and fourth. For the first vegetation component, the regression on the first, second and sixth environmental components accounted for 53.6 per cent of the variability. For the fourth component, the regression on the first, second, fourth, fifth and sixth environmental components accounted for 31.5 per cent of the total variability. The table suggests that most of the variability in the vegetation is controlled by factors other than those measured by the environmental variables.

As examples of predictors of individual vegetation variables, the equations:-

$$\hat{V}_1 = 1.447 - 0.0115\ X_1 + 0.0993\ X_6$$

and

$$\hat{V}_8 = 7.761 - 0.0275\ X_1 - 0.00125\ X_7$$

where V_1 = percentage of continuous moss carpet

V_8 = percentage area modified by birds and seals

X_1 = maximum altitude

X_6 = percentage of drift and scree

X_7 = distance to sea to east

account for 35.3 per cent and 19.7 per cent of the total variability of V_1 and V_8 respectively, with standard deviations from regression of 3.70 and 5.66. Similar equations can be derived for all of the vegetation variables.

Similarly, the equations:

$$\hat{V}_{14} = 0.539 - 0.00187\ X_1 - 0.00339\ X_3$$

and

$$\hat{V}_{14} = 0.178 + 0.-3071\ V_3 + 0.01269\ V_5 - 0.00827\ V_6 + 0.03934\ V_{10}$$

where V_{14} = presence (1) or absence (0) of vascular plants

X_1 = maximum altitude

X_3 = percentage of slope facing south

V_3 = percentage of continuous moss turf

V_5 = percentage of continuous lichen moss

V_6 = percentage of discontinuous lichen moss

V_{10} = percentage of continuous mosaics of carpet/lichen and moss

Table 20 Prediction of vegetation components from environmental components

Vegetation component	Regression constant	Regression coefficient of environmental component: I	II	III	IV	V	VI	VII	R^2
I	0.000	-0.169	-0.567				-0.600		0.536
II	0.000			0.182	-0.242	-0.275			0.166
III	0.000		0.250						0.177
IV	0.000	0.126	-0.114		0.241		0.183	-0.319	0.315
V	0.000	0.113	-0.164						0.149
VI	0.000	0.079	0.116						0.108
VII	-	-	-	-	-	-	-	-	-

account for 20.5 per cent and 31.7 per cent of the total variability of V_{14} with standard deviations from regression of 0.37 and 0.35.

As an alternative way of expressing the same relationships, the function:

$$Z_1 = -0.01385\ X_1 - 0.02505\ X_6$$

gives significant discrimination between the presence and absence of vascular plants, with centroids of -1.226 and -2.743, and a generalized distance of 1.518. Similarly, the function:

$$Z_2 = 0.264\ V_3 + 0.109\ V_5 - 0.071\ V_6 + 0.038\ V_{10}$$

provides significant discrimination between the presence and absence of vascular plants, with centroids of 2.44 and -0.29, and a generalized distance of 2.723.

Summary and conclusions

Analysis of 22 environmental variables and 13 vegetation variables, derived from maps for 104 squares of an arbitrary 500 m^2 grid imposed on the 1:25,000 scale map of Signy Island, indicates seven orthogonal dimensions of environmental variability and a further seven orthogonal dimensions of variation in the vegetation. As might be expected, there was some correlation between the dimensions (or components) describing the variation of the environment and that of the vegetation, but the environmental variables, alone or in aggregate, accounted for a relatively small proportion of the variation in vegetation.

Nevertheless, the variables and the weighted linear functions of these variables represented by the components provide a useful characterization of the island, and suggest stratifications for future sampling. The clusters based on environmental and vegetation components, while only partly correlated, indicate the range of variation over the island, and suggest possible areas for further investigation. In particular, it would be important to see that any future research adequately covered the full range of environmental and vegetation variation.

It is not the intention of the case study to suggest that the ecological characterization illustrated is an alternative to field ecological survey, still less that the methods used should inhibit speculation and the formulation of hypotheses. Rather, it is intended to show the benefits of survey which covers the whole area so as to provide an ecological characterization which would complement (and perhaps also guide) detailed research at a small number of study sites.

Furthermore, the methods used in this study are primarily focussed on the reduction of the number of variables required to describe the full range of variation to the smallest possible set. In this way, further ecological characterization can be concentrated on new variables which, added to those retained as a result of this analysis, will increase the number of dimensions of the total variability. Ecological research is an iterative process which should be capable of building on past data rather than having to start afresh at each new stage.

References

N. J. Collins, J. H. Baker and P. J. Tilbrook, 1975. Signy Island, maritime Antarctic. In: Rosswall, T. and Heal, O. W. (Editors) Structure and function of tundra ecosystems. Ecol. Bull. (Stockholm) 20, 345-374.

M. W. Holdgate, 1967. Signy Island. Phil. Trans. Roy. Soc. Lond., B, 252, 173-177.

J. N. R. Jeffers, 1969a. Multivariate statistical analysis in the search for basic factors in forest site classification. Merlewood Research and Development Paper No. 7.

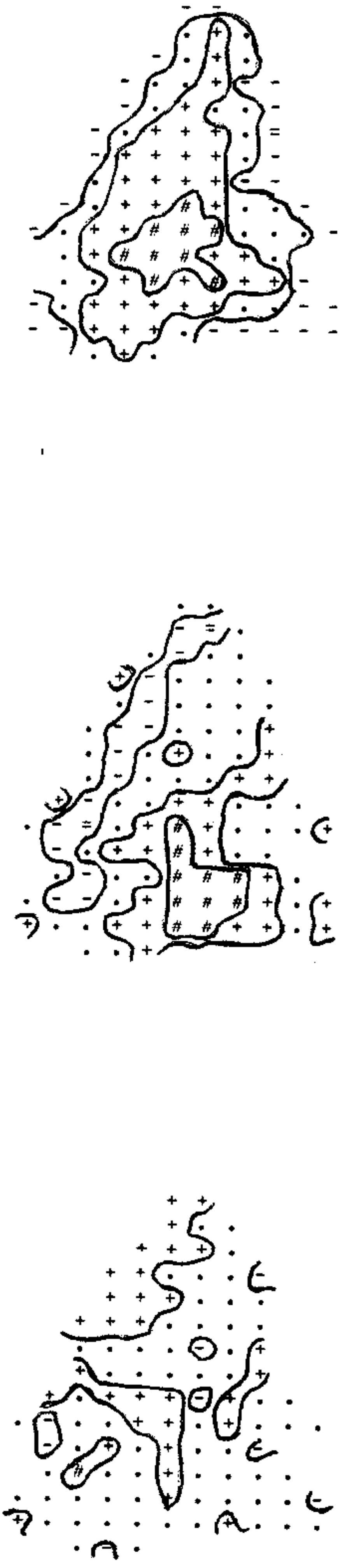
J. N. R. Jeffers, 1969b. Principal component analysis of physical and chemical data from a pilot survey of Morecambe Bay. Merlewood Research and Development Paper No. 15.

R. E. Longton, 1967. The vegetation in the maritime Antarctic. Phil. Trans. Roy. Soc. Lond., B, 252, 213-

D. H. Matthews and D. H. Maling, 1967. The geology of the South Orkney Islands: 1. Signy Island. Falkland Islands Dependencies Survey, Scientific Reports No. 25, 1-32.

R. I. L. Smith, 1972. Vegetation of the South Orkney Islands with particular reference to Signy Island. Scient. Rep. Br. Antarc. Surv. 68, 1-124.

Figure 1

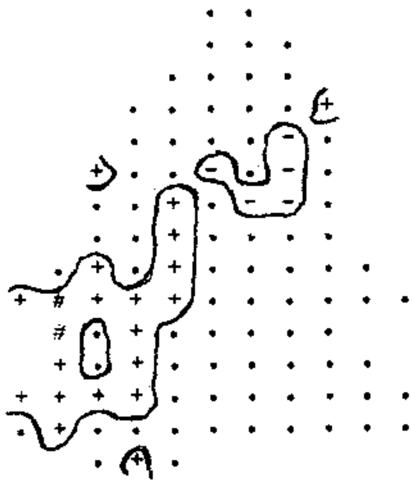


Component I

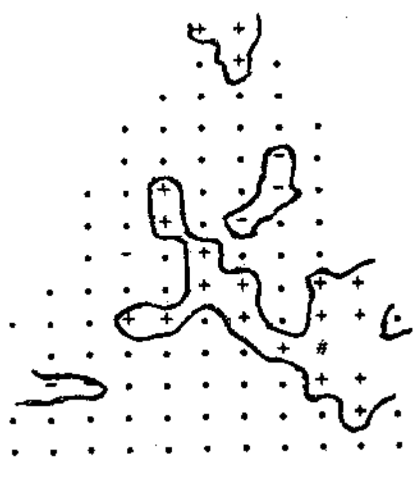
Component II

Component III

Figure 1 (continued)



Component IV



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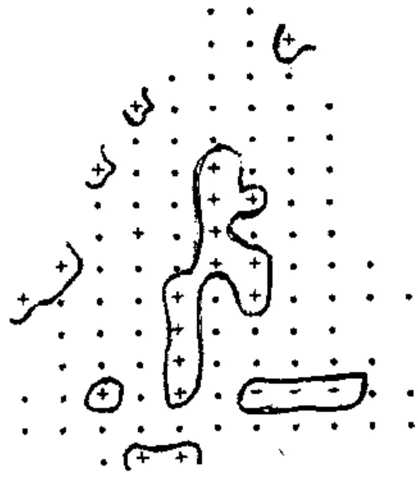
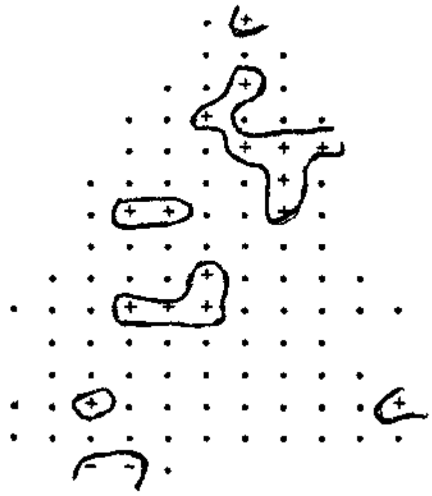


Component VI

Figure 1 (continued)



Component VII

Figure 2. Projection of clusters on first and second components

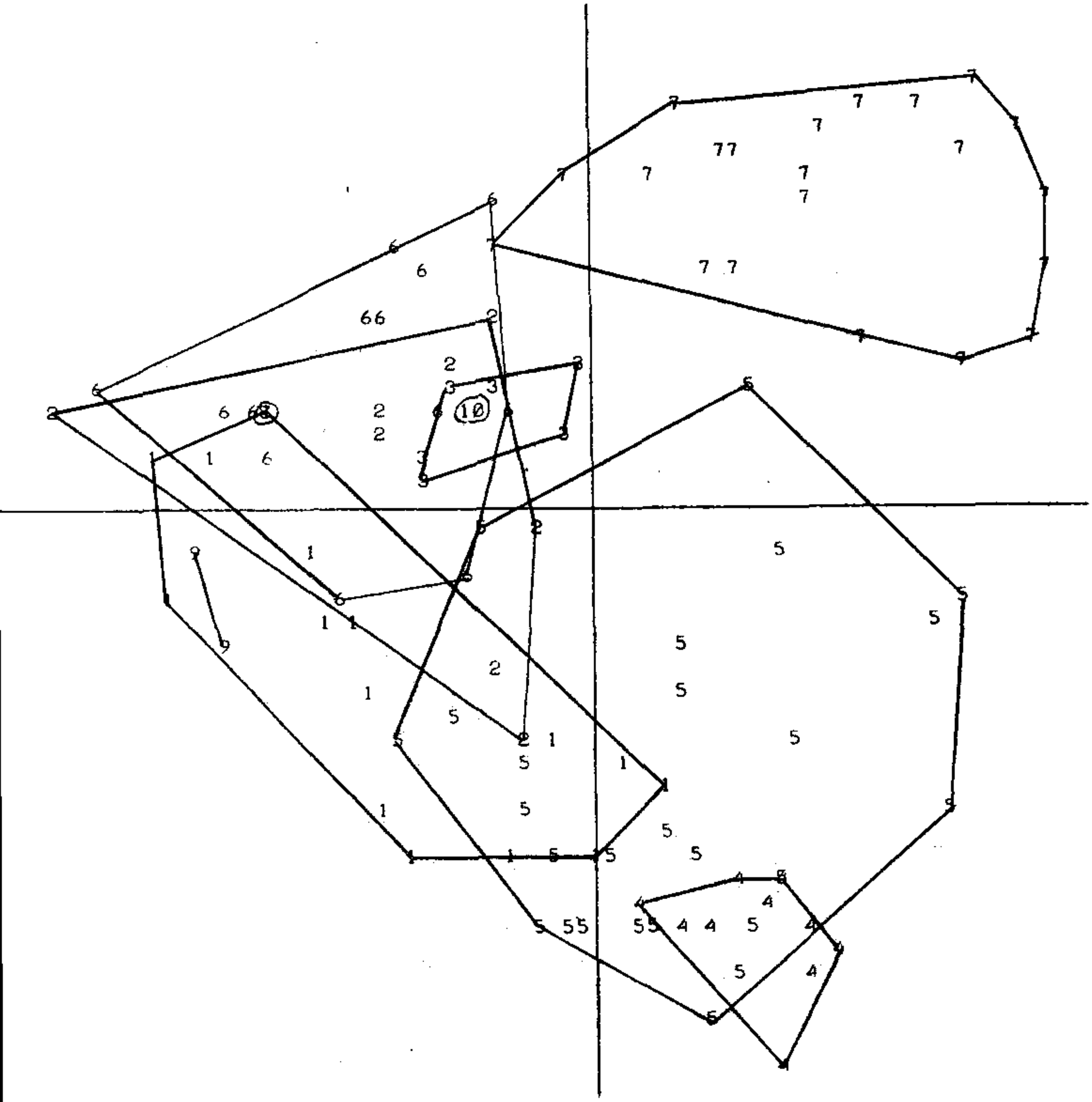


Figure 3. **Geographic distribution of environmental clusters**

					1	1				
					1	2	1			
				1	1	3	1			
			4	1	3	3	5	5		
			4	1	3	2	2	5		
		4	1	1	2	2	2	4		
		1	6	6	7	2	5	4		
		1	8	6	7	2	5	4		
	4	6	6	7	7	7	1	5	5	
5	9	6	7	7	7	7	3	5	5	4
	9	6	7	7	7	7	3	5		
	5	1	6	7	7	7	7	5	5	
5	6	6	6	7	7	7	5	5	5	5
4	5	6	7	7	5	5	4	5	5	5
		6	0	5						

Figure 4.

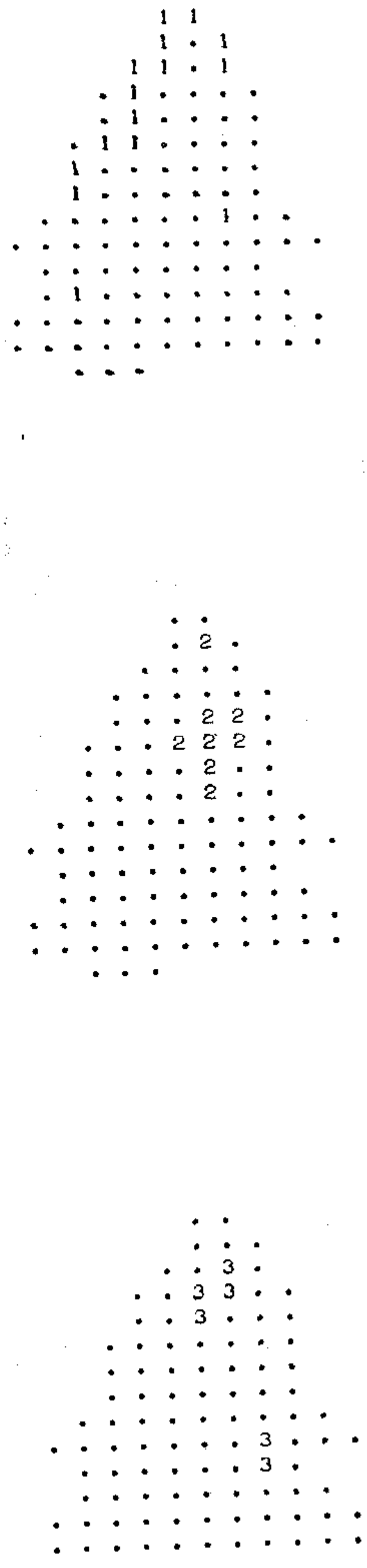


Figure 4 (continued)

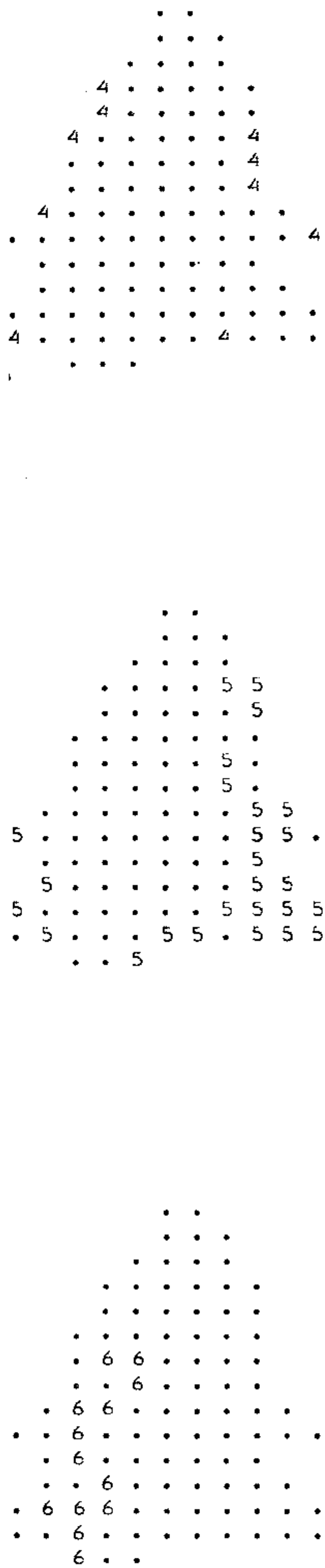


Figure 4 (continued)

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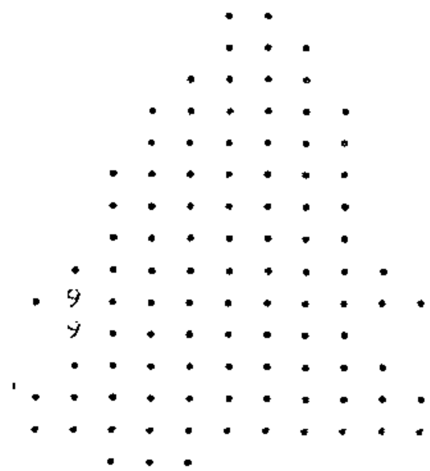
Figure 4 (continued)



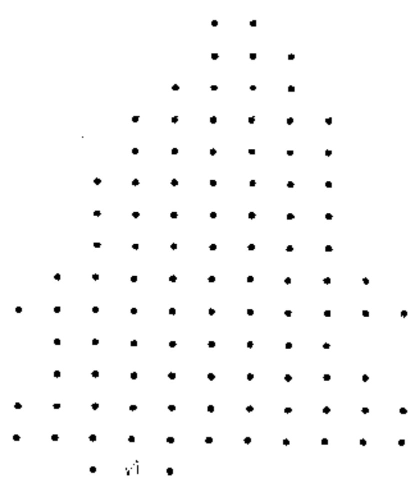
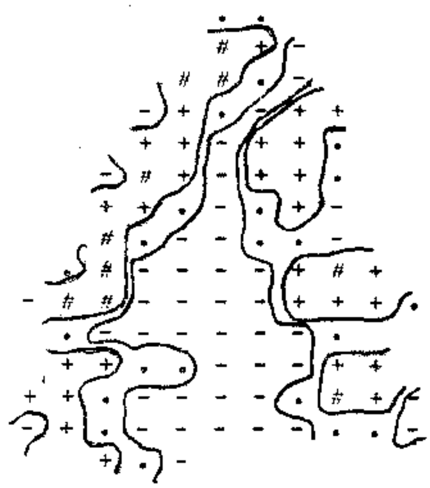


Figure 5.



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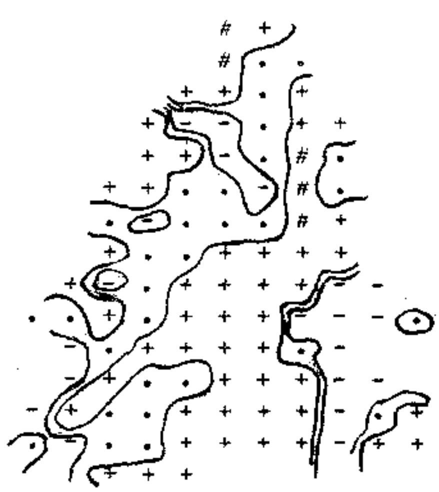
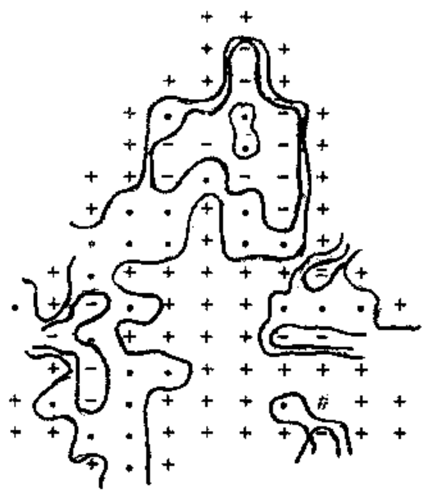
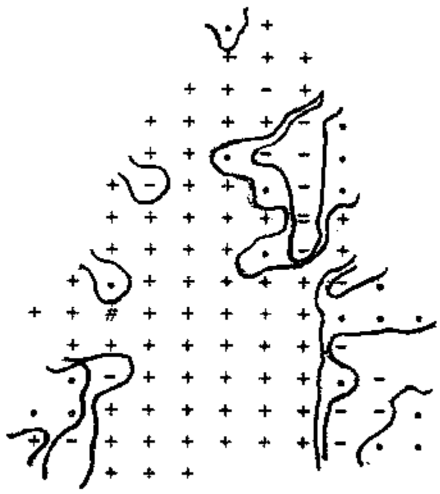


Component II

Figure 5 (continued)

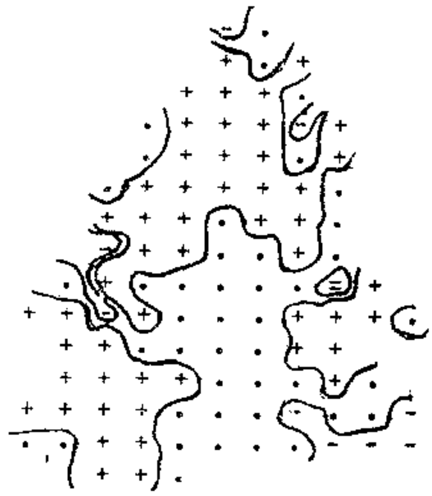


Component III

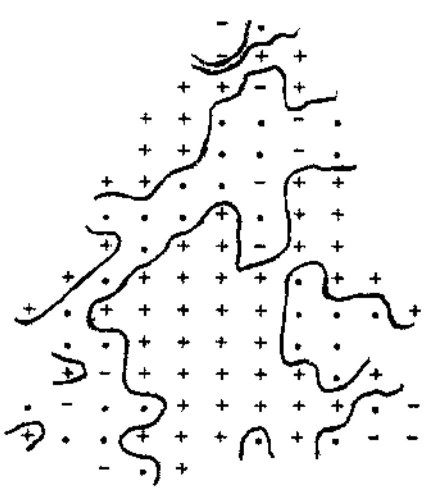


Component IV

Figure 5. (continued)

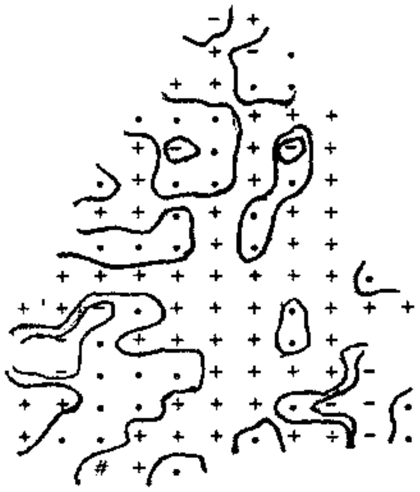


Component V



Component VI

Figure 5 (continued)

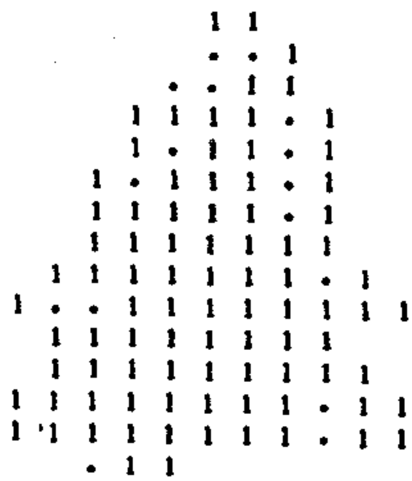


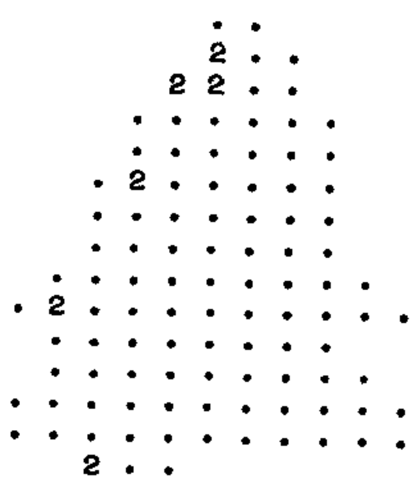
Component VII

Figure 6. Geographical distribution of vegetation clusters

					1	1				
					2	3	1			
				2	2	1	1			
			1	1	1	1	4	1		
			1	3	1	1	5	1		
		1	2	1	1	1	5	1		
		1	1	1	1	1	5	1		
		1	1	1	1	1	1	1		
	1	1	1	1	1	1	1	6	1	
1	2	3	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1		
	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	7	1	1
1	1	1	1	1	1	1	1	4	1	1
		2	1	1						

Figure 7.





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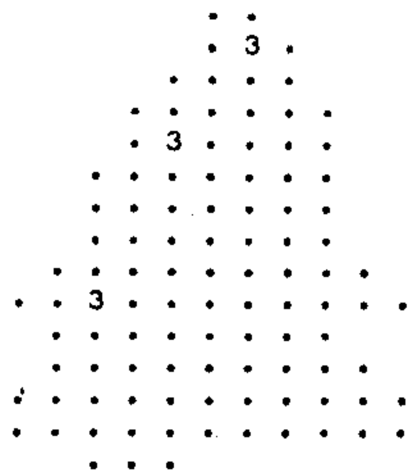

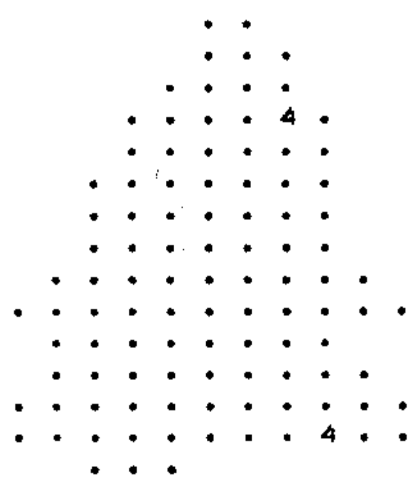

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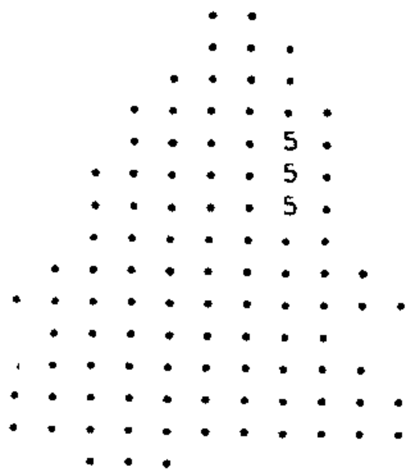

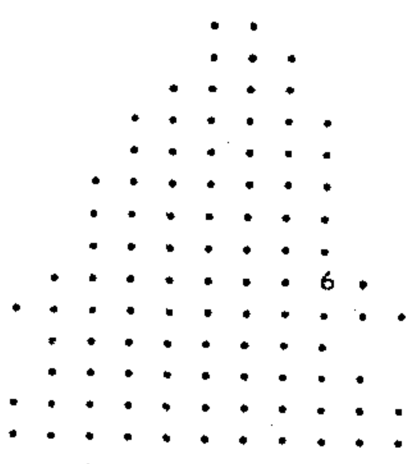

Figure 7 (continued)

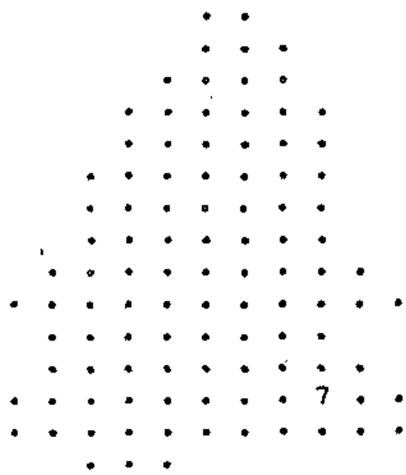

Figure 8. Geographical distribution of sub-groups of first vegetation cluster

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          1 2
          . . 3
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      2 5 4 4 . 4
      2 . 4 4 . 4
    2 . 5 4 5 . 2
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    2 4 4 3 4 4 2
  2 5 3 2 2 2 2 . 6
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Figure 9

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Figure 9 (continued)

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                .   .   .   3
            .   .   .   .   .   .
            .   .   .   .   .   .
        .   .   .   .   .   .   .
        .   .   .   3   .   .   .
        .   .   .   3   .   .   .
    .   .   3   .   .   .   .   .   .
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        .   .   3
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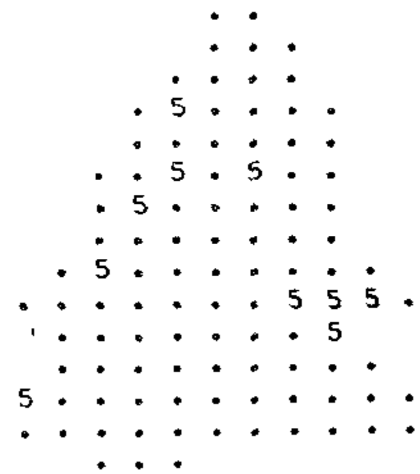
                .   .   4   .
            .   .   4   4   .   4
            .   .   4   4   .   4
        .   .   .   4   .   .   .
        .   .   4   .   4   .   .
        .   4   4   .   4   4   .
    .   .   .   .   .   .   .   .   .
4   .   .   4   .   .   .   .   .   .   .
    4   4   .   .   .   .   4   .
    .   4   4   4   .   .   .   .   .
.   4   4   4   .   .   .   .   .   .   .
.   .   4   4   .   .   .   .   .   .   .
        .   4   .
```

Figure 9 (continued)



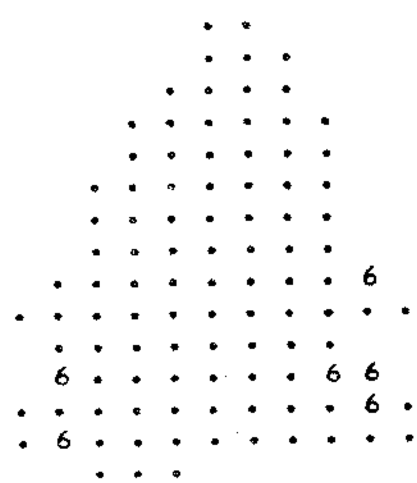


Figure 10. Location of squares with vascular plants

```
          1 1
          1 . .
        1 . . .
      . . . . . 1
      . . . . . 1
    1 1 . . . . 1
    . . . . . . 1
    1 . . . . . 1
  . 1 . . . . 1 1 1
. 1 . . . . . . . 1 1
  . . . . . . . .
  . . . . . . . . 1
1 . . . . . . . . 1 .
. . . . . . . . . . .
    . . .
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