A PRELIMENARY SURVEY OF SOIL NUTRIENT STATUS AND VEGETATION DISTRIBUTION IN KIRSTENBOSCH

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Botany Honours 1976

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C.BOTHA: HONOURS PROJECT

This interesting study of soils and plant communities of selected sites in Kirstenbosch has been fairly well done. It is unfortunate that soil analysis is such a time consuming operation at U.C.T., where the facilities for doing such work are rather poor. With better soil data this project may have shown other interesting trends, but, in my opinion, the candidate has done a fair number of analyses and has interesting results (even if they are somewhat tentative).

The discussion is good and makes interesting reading. The report is neatly and clearly presented, but somehow lacks a little in originality and synthesis to deserve a higher mark.

Dr. E.J. MOLL

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CONTENT

INTRODUCTION

Though the soils of large areas of South Africa are known to be generally deficient in important nutrients, like phosphorus, (Fourie, 1974 pers. comm.) very few observations have been made on the exact nutrient status of soils supporting fynbos and montane forest in the Western Cape. The presence of soil nutrients and its availability to the plant, is governed by several factors, notably parent material, soil texture, climate, chemical interactions between the soil and nutrients as well as competition among roots (Wilde 1959, Nye 1954)

The Cape fynbos is a rich and diverse flora which occurs on sandy, acidic soils which are derived from Table Mountain Sandstone, granite, Malmesbury shales or Recent Sands, and these soils have a low phosphate content. This situation is analogous to the plant-soil relation of Australian sclerophyll which is also found on nutrient-poor, acidic sands (Beadle 1966, Loveless 1961). An investigation into the soil factors influencing the fynbos as well as some aspects of the physiology and anatomy of this vegetation type, should provide useful information about the exact nature of the plant-soil interactions.

The present investigation into the soil nutrient status and vegetation of an area in Kirstenbosch Botanical Gardens, is aimed at providing an idea of the range of nutrient levels in fynbos and montane forest soils. The soil analysis involved an assessment of phosphorus, nitrogen and organic matter in the soil, all of which are important factors in

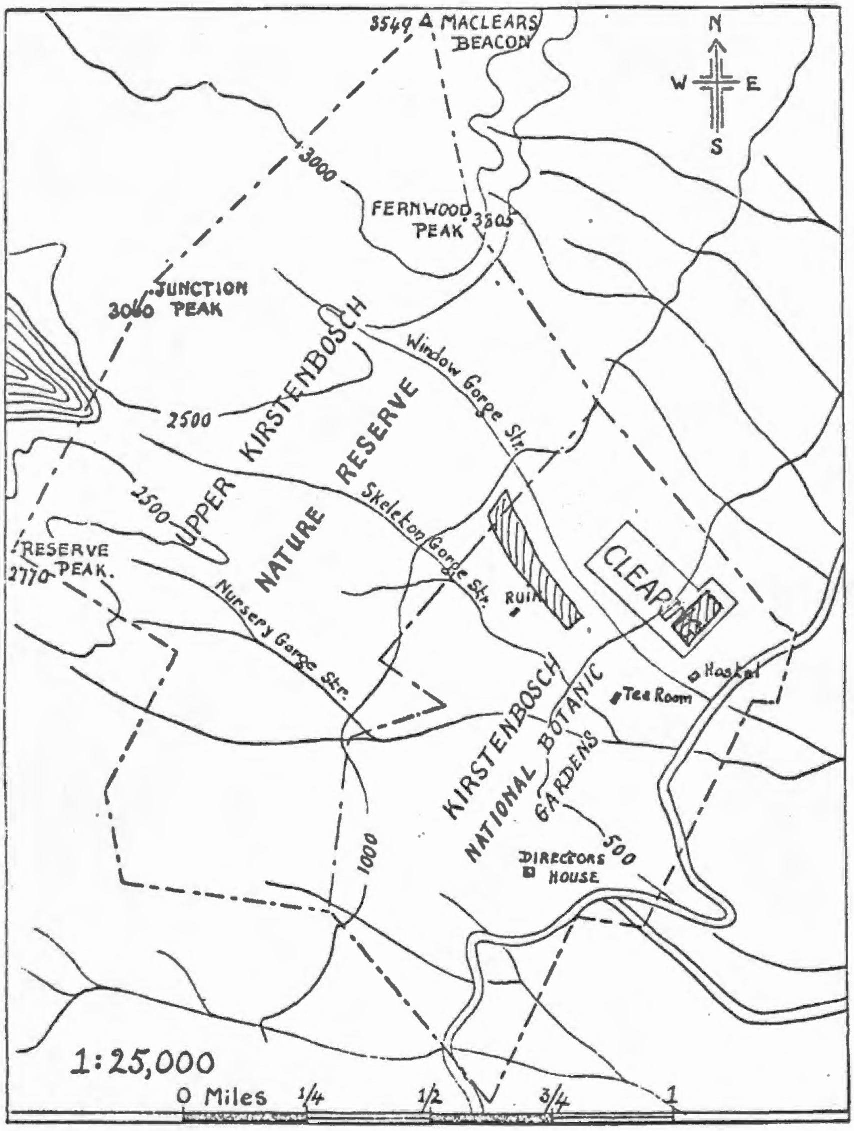

FIG. 1. Plan of Kirstenbosch, showing position of Clearing. (Del. W. F. Barker.)

▨ Hatched areas indicate study area.
Clearing is study area of Esterhuizen (1936).

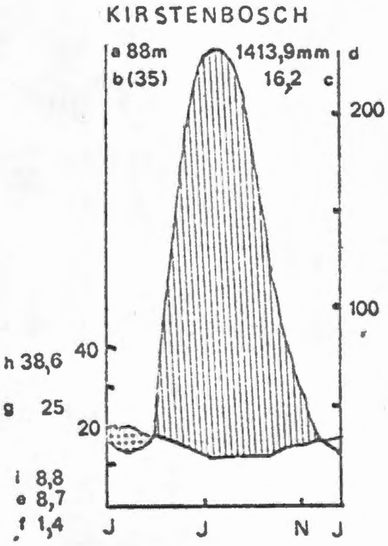

Figure 2. Climate diagram of Kirstenbosch.

a = altitude (m)
b = number of years of observation
c = mean annual temperature (°C)
d = mean annual precipitation
e = mean minimum temperature of coldest month
f = absolute minimum temperature
g = mean daily maximum temperature of hottest month
h = absolute maximum temperature
i = mean range of temperature

determining soil fertility. The possibility of a correlation of vegetation with soil nutrient status was also investigated. Any inferences made from the results, should be regarded as tentative. A much more elaborate study is required to provide a sound basis for detailed discussion of the situation in our fynbos and montane forest.

THE ENVIRONMENT

The Study Area   Two areas in the Kirstenbosch Botanical Gardens were selected for study. One area formed part of the montane forest and the other part of the fynbos growing naturally in the 'back garden'. The areas were separated by the Window Gorge (Figure 1 Map of Kirstenbosch).

The forest extends some way up the slopes of Table Mountain as well as along the banks of a stream flowing from Window Gorge. Fynbos and some scrub grow on a talus slope adjacent to Window Gorge. The habitat of the talus slope is generally drier than the forest habitat, except for the part boarding on the stream-banks where forest and forest precursor species predominate.

Twenty sample sites were chosen, ranging from pure forest through mixed scrub to fynbos. Soil samples were taken and vegetation analyses performed at each site.

Climate   The climate of Kirstenbosch is summarized in Figure 2 (Climate Diagram of Kirstenbosch). Mean annual precipitation is 1413,9 mm with a peak of rainfall in the winter months and very little in summer. The forest areas occurring on open slopes in Kistenbosch are probably less affected by mist on the mountain, than forest growing in Window Gorge, although the lowest mist line lies at about 160 m. Temperatures are relatively mild, ranging from $\pm$ 12°C in winter to $\pm$ 22°C in summer, but very high temparatures in summer are not uncommon to the Cape Peninsula. Little or no frost occurs in the Kirstenbosch area (Campbell 1975).

Geology, Topography and Soils The forest and fynbos in the study area are situated on moderate to steep south-east facing slopes which are fairly exposed. Moister conditions in the forest area are due primarily to the modifying influence of the vegetation.

The soils in Kirstenbosch are derived from Cape granite, Table Mountain Sandstone and Malmesbury shales. Soils in the forest area overlie granite, while boulders of T.M. Sandstone are scattered over the area. These soils are generally less sandy than the fynbos soils (Table 1) where quartzites and sandstone contributed to soil formation to a larger extent. The talus slope (fynbos area) was formed by rocks of sandstone which accumulated over Cape granite (Esterhuizen 1935).

According to the standard soil classification system of South Africa, the forest soils were found to be of Hutton Form and the fynbos soils of Fernwood Form (Table 1). Both soil types have a sandy, diagnostic A_q horison (orthic) which is of dark-brown colour in the forest and dark-grey in the fynbos.

In the Hutton Form, this A_o horison overlies an apedal Bhorison which is red-brown sandy loam in the forest. The Fernwood Form in the fynbos area has a B horison of regic sand. At two sites in the fynbos area ther are evidence of a better developed Fernwood soil i.e. theseprofiles have an A_2 horison between the A1 and B horisons.

Only one soil profile was of a different soil form, i.e. the Longlands Form. This soil form has a sandy orthic A_o horison overlying perched gley and a soft plinthic B horison. Yellow mottling in the B horison indicates iron oxide formation (MacVicar 1975). This area probably experiences a fluctuating water table from time to time and seems to be poorly drained.

History of Disturbance   Kirstenbosch was listed as a 'high impact' area during a survey of the Table Mountain area by Moll and Campbell (1975). Both forest and fynbos areas have a long history of disturbance and are still subject to intense human activities.

For fifty years, up to 1933 - 35 the present fynbos area was totally covered by Pinus pinaster (Esterhuizen 1935). The area was then cleared by felling and burning debris. Fynbos successfully recolonized the area and Esterhuizen (1935) gave a full account of species that occurred there during regeneration. The fynbos was subsequently invaded by alien vegetation e.g. regenerating Pinus pinaster, and mostly Acacia longifolia and Acacia saligna, which persisted until about 1961 (Marais, pers. comm.). The fynbos area was systematically cleared of aliens during the period 1961 to 1963. Fynbos presently occupying the area is, on average, about fifteen years old.

The forest is much older than the fynbos. Invasion by Rubus fruticosus occurred and these dense growths still have to be removed and burnt periodically. This confers the loss of some indigenous undergrowth and litter. In general, the forest undergrowth is poor, except for small areas where forest species are regenerating after a major disturbance, as for example tree felling of which there is much evidence in the forest area.

Due to human disturbance, which is quite frequent, the vegetation on the whole tends to be patchy, which complicates the choice of reasonably homogeneous sites - a first requirement for the Braun-Blanquet method of vegetation analysis. Another consequence of disturbance, is the wide-spread occurrance of several weeds and other species associated with the initial stages in regeneration.

METHODS

Soil Analysis All chemical determinations were performed on air-dried soil samples which had been passed through a 1.7 mm sieve. The samples were taken from three levels in the soil profile and kept seperate to demonstrate any vertical gradients in nutrient distribution throughout the soil.

The determination of soil reaction and available phosphorus were done according to the methods recommended by the Fertilizer Society of South Africa (Soil Analysis Methods, Publication No. 37).

1. Soil Reaction (pH) Soil reaction was determined from 1 : 2,5 soil/1N KCl mixtures, using a pH meter.

2. Available Phosphorus Available phosphorus was extracted in HCl by shaking soil samples with Bray No. 2 solution for 50 minutes and determined colorimetrically by the molybdenum blue method.

3. Total Nitrogen Total nitrogen was determined by a semi-micro Kjeldahl method (modified to include nitrate-nitrogen). Soil samples were digested in a mixture of concentrated H_2SO_4 and salicylic acid (Jackson 1958).

4. Organic Matter The method used for the determination of organic matter was a modification of Mitchell's (1932). Soil samples were ignited at 600°C in a muffel furnace for five hours. Loss-on-ignition was taken as the amount of organic matter in the sample.

5. Soil Particle Size The proportional distribution of different particle sizes in the soil was determined by shaking a known volume of soil (ca 1 kg) at high speed (60 r.p.m.) for ten to twenty minutes in a sieve nest. Soils were crudely graded according to the percentage of aggregates and particle

sizes present, using the following scale:

Sand	90 % sand
Loamy sand	80 % sand
Sandy loam	70 % sand

The sieve method did not give actual proportions of particle sizes in the soil samples. Clay, fine sand and silt fractions were under-estimated, especially in the forest soils. For a final judgement of soil texture, the finger test was performed.

6. Litter Litter was collected manually from four 0,25 m^2 quadrats placed within each sample site. Litter was defined in this instance, as all fallen leaves, and twigs with a diameter of less than 0,5 cm. This was done to avoid unrealistically high litter values due to thick wood and bark. The object of litter collection was to gain some impression of the qualitative differences in litter production at the various sites. After collection, the litter was air-dried for 24 hours and then oven-dried at 80°C overnight, cooled and weighed.

7. Vegetation For an account of the vegetation present on the sample sites in the study area, a Braun-Blanquet vegetation alalysis was performed at each site. This was done according to an account of the method as given by Westhofft and Van den Maarel (1973).

RESULTS

The results of determinations of soil reaction, available phosphorus, total nitrogen, organic matter and soil type are given in Table 2. Means and standard errors were calculated from three replicates in each case.

Only mean values are given in Table 2. The figures are given in a sequence corresponping to the plot sequence of the vegetation table (Appendix 1). In order to facilitate comparison and correlation, information about the general features of the vegetation at the sample sites was included with the soil data in Table 2.

1. Soil reaction The fynbos soils are more acidic (pH 4) than the forest soils (pH 4 to pH 6). This indicates the rise in pH during the succession from fynbos, through scrub to forest. In the fynbos soils a vertical gradient in pH of soil is virtually absent, but in the better developed forest soils there is a tendency for sub-soils to have a lower pH than near the soil surface.

2. Available Phosphorus Available phosphorus (i.e. HCl extractable) is neither a measure of total phosphorus in the soil, nor does it give an indication of the amount of phosphorus actually utilized by the plant. Plants differ as much in their nutrient requirements as in their ability of extracting nutrients from the soil.

The amounts of available phosphorus are very variable, which may be attributed to several factors. For instance, the method used is known to be accurate over a relatively narrow range and this could have resulted in some inaccurate values. However, this point need not be stressed, as the survey is only a prelimenary one not requiring great accuracy. In the forest soil samples the phosphorus levels are extremely low. This is attributable to some amount of fixation of phosphate as organo-phosphorus which may be even less available to the roots (Salisbury 1959). On the other hand, phosphorus is readily extractable from the fynbos soils. A possible explanation lies in the soil reaction. Acidic soils with a pH of more than 3 probably allow phosphates to be more readily soluble and thus more easily taken up by the roots. Only below pH 3 does the soil particles react with the phosphate causing fixation and unavailability to the roots (Nye 1954)

In general, phosphate levels are very low, as compared with tropical forest soils, savanna, etc. (Philips 1959). There is a tendency for available phosphorus to decrease with depth of soil, indicating that leaching has taken place.

3. <u>Total Nitrogen</u> Total nitrogen values are also very variable, probably owing to experimental error and the variability in micro-organism populations in the soil. Micro-organisms contribute to total nitrogen of the soil by fixed organic nitrogen. In the forest total nitrogen levels are the highest, mostly of the order of five times higher than in the fynbos soils. Thus, there is a definite rise in the nitrogen status of the soil during succession, in which the presence of micro-organisms play a large rôle. Total nitrogen levels also exhibit a pronounced gradient in the soil profiles, decreasing from the topsoil to deeper layers, where it may be up to three times less. The variations in total nitrogen paralleled the changes in soil pH and organic matter. This may be indicative of the influence of soil reaction on the presence of soil micro-organisms.

4. <u>Organic Matter</u> The organic matter content of the fynbos soils is generally much lower than the forest soils Although this increase in organic matter of the soil could not be directly correlated with a quantitative increase in litter, the higher organic content of the forest is doubtlessly due to a higher rate of litter production and probably incorporation into the soil. Fynbos litter can be expected to be decomposed at a different rate and incorpo-

rated by different means as well. The complete absence of earth worms from fynbos soils is a point to notice. According to Schutte (pers. comm.) dead leaves and other litter in the fynbos may become mixed into the soil by wind-action or rainfall. In the fynbos litter tends to form a crust on top of the soil, which could then slowly become consolidated with the topsoil. Very little to no humus is present in these soils.

Forest soil samples contained more soil fauna, which contribute to the incorporation of litter into the soil. Low pH values are known to exclude sensitive organism like earth worms from soil. While the soil reaction in the forest soils is acidic, the presence of substantial amounts of organic matter ensures buffering of the soil pH which may be instrumental in maintaining a reasonably stable environment for the more sensitive soil fauna.

It is yet unknown how great a part the nature of the litter itself plays in its rate of decomposition and consolidation. Beadle (1966) remarked that the litter of Australian sclerephyll is very acidic and the fynbos litter is highly likely to have the same feature.

5. <u>Soil Particle Sizes</u> According to the grading system used (refer to Methods, p 7), all fynbos soils are sandy, ranging from coarse sand to predominantly medium/fine sand. In the forest area, soils are mostly of a loamy sand to sandy loam texture and have higher silt and clay fractions than the fynbos soils. The sieve method did, however, not show this tendency. Only one sample area has soil with a substantial amount of clay, namely, Profile 18, which is Longlands Form (Table 1).

6. <u>Litter</u> Quantitatively the forest and fynbos litter do not differ. In this respect, dry weights were found to be more consistent than fresh weights as a measure of litter production (Table 3). Qualitatively, there are

notable differences from plot to plot. In the fynbos, ericoid leaves and flowers contribute largely to litter, followed by twigs. The twigs and larger branches become more important where a whole plant has died and is in the process of breaking up. Tree species contribute a sizable amount to litter through leaf and twig fall, bark, branches, etc. This happens in scrub adjacent to fynbos and especially, in the forest. Alien vegetation like Quercus robur (in the forest) and Acacia spp. also add to the leaf litter. Quercus leaf litter forms the greater part of dead plant material in marginal parts of the forest.

The sampling method, though very crude, gives an idea of the qualitative differences in litter. For an investigation of litter production, litter traps should be set up in the forest and fynbos areas. Such a study should be very helpful indeed, as it is a further step towards understanding nutrient cycling in fynbos and forest. An analysis of the chemical properties of the litter could form part of such a study. Because of lack of time,this aspect of the fynbos and forest litter could not be investigated during the present study, but in the light of the definite qualitative differences found, this would seem to be an important factor requiring attention.

7. Vegetation A short general account of the vegetation of the study area should suffice for discussion of a possible soil-vegetation correlation.

The forest and fynbos communities constitute two distinct groups of vegetation. The fynbos community, in total, consists of two partially overlapping sub-groups. These are an Erica-Blaeria facies and a Leucospermum-Widdringtonia facies. Within both sub-groups there are species of localized occurrence and others common to both. The fynbos community also intergrades with scrub and forest precursors. Species belonging to this widely occuring transitory group are Podalyria calyptrata, Rhus tomentosa and Passerina vulgaris.

In the forest area, the dominants are Diospyros whyteana, Kiggelaria africana, Halleria lucida and Rapanea melanphloes. These form the highest stratum and are wide-spread in the forest. Young individuals of these species together with Canthium ventosum and Canthium mundianum form the subordinate strata. Various herbaceous species, geophytes and grasses form the lowest stratum. Some of frequent occurrence are Knowltonia capensis, Senecio spp., Watsonia and Chasmanthe aetheopica.

Where forest vegetation has been removed or disturbed, the area bears forest precursors, notably Virgilia oroboides, and tall scrub, for example, Maytenus heterophylla, Podalyria calyptrata, Polygala myrtifolia, Rhus tomentosa and others. Disturbance is, as already explained (pg 6), and have been for a long time, an important factor in the distribution and structure of the vegetation of the area. My own opinion is that this is the main reason for the wide-spread occurrance of various herbaceous weeds and/or introduced species in the area. A few examples are Hypochoerus radicata, Senecio spp, Drougetia ambigua, Briza spp, Cedronella triphylla. These constitute a broad, undiagnostic group in the final vegetation table as arranged from plot data (Appendix 1).

TABLE 1. Classification of soil profiles. Distribution of soil particle sizes given as percentages. Abbreviations: C.Sa = course sand ; M.Sa = medium sand ; F.Sa = fine sand ; C = clay ; Si = silt.

PROFILE		SOIL FORM	>2mm	2 - 0,5 mm C.Sa	0,5-0,2 mm M.Sa	0,2-0,02 mm F.Sa	<0,02mm Si/C	COLOUR	SOIL TYPE
2	A	Fernwood	3,9	56,30	22,57	14,76	1,81	Dark-grey	Coarse sand
	B		1,18	58,81	21,05	16,55	2,27	Light grey	C. to Med sand
1	A	Fernwood	2,17	42,25	27,84	23,80	3,54	Dark-grey	Coarse-medium sand
	B		1,71	49,15	25,57	21,09	2,36	Light grey	Coarse-medium sand
8	A_1	Fernwood	4,61	74,40	25,70	14,83	0,93	Black-grey	Coarse sand
	A_2		4,44	53,52	20,63	9,61	1,8	Red-brown	Coarse-medium sand
	B		0,82	52,13	25,88	18,59	2,06	Light grey	Coarse-medium sand
3	A	Fernwood	5,32	42,25	28,24	20,66	2,60	Black-grey	Medium sand
	B		3,30	40,14	29,14	24,53	2,83	Light grey	Medium sand
5	A	Fernwood	15,18	50,66	33,58	17,0	1,95	Black	Coarse sand
	B		4,78	50,04	22,45	20,40	2,42	Dark-grey	Coarse-medium sand
4	A	Fernwood	7,55	30,42	33,63	25,70	2,06	Black-grey	Medium-fine sand
	B		2,95	37,54	32,31	25,21	1,87	Dark-grey	Medium-fine sand
7	A	Fernwood ?	9,40	39,70	23,19	23,80	3,80	Dark-brown	Medium -course sand
	B		9,74	38,20	18,40	27,97	5,0	Red-brown	Coarse-medium sand
9	A	Fernwood	2,09	61,0	9,05	14,75	2,2	Black-grey	Coarse sand
	B		0,61	82,73	9,61	5,55	0,65	Light grey	Coarse sand
6	A	Fernwood ?	10,46	42,79	18,55	23,41	4,54	Black	Medium-fine sand
	B		21,28	37,52	17,34	19,74	3,17	Dark-brown	Sandy loam
10	A_1	Fernwood	5,43	61,46	17,47	13,84	3,32	Black-grey	Coarse-medium sand
	A_2		3,54	43,04	25,94	22,92	0,96	Grey-brown	Medium sand
	B		0,61	86,05	6,29	6,82	0,99	Light grey	Medium sand
19	A_1	Fernwood ?	41,80	48,80	9,20	9,20	0,98	Black	Coarse-medium sand
	A_2		29,70	42,30	13,90	13,20	1,36	Dark-brown	Medium-fine sand
	B		17,70	58,30	11,80	11,70	1,00	Dark-brown	Medium-fine sand
18	A_1	Longlands	37,20	40,70	10,40	11,00	1,05	Dark-brown	Medium sand
	A_2		49,20	35,90	7,80	6,36	0,40	Red-brown	Sandy loam
	B		49,90	45,30	2,80	1,93	0,18	Orange-brown	Clay loam
17	A_1	Hutton	30,10	39,40	12,30	15,60	2,60	Dark-brown	Sandy loam
	A_2		32,60	44,40	9,70	11,50	1,70	Dark-brown	Sandy loam
	B		32,00	48,30	8,80	9,27	1,40	Dark-brown	Sandy loam
16	A_1	Hutton	19,70	52,80	9,70	16,00	1,70	Black	Sandy loam
	A_2		16,86	40,00	17,60	23,60	2,45	Dark-brown	Sandy loam
	B		20,16	53,55	11,80	13,15	1,50	Red-brfown	Sandy loam
12	A_1	Hutton	40,50	40,80	8,50	9,10	0,90	Black-brown	Sandy loam
	A_2		41,10	40,75	8,60	8,36	0,85	Dark-brown	Sandy loam
	B		45.10	41.00	7.00	5,80	0.40	Dark-brown	Sandy loam
15	A_1	Hutton	21,40	55,90	10,60	11,20	1,16	Black	Sandy loam
	A_2		29,00	53,50	9,00	7,25	1,20	Dark redbrown	Sandy loam
	B		43,20	47,70	4,40	4,10	0,50	Dark redbrown	Sandy loam
14	A_1	Hutton	22,40	45,50	15,00	16,30	1,79	Dark-brown	Sandy loam
	A_2		27,50	46,40	12,50	13,00	1,00	Dark-brown	Sandy loam
	B		24,60	53,10	11,80	9,60	7,50	Red-brown	Sandy loam
13	A_1	Hutton	29,40	38,00	13,50	16,70	1,65	Dark-brown	Sandy loam
	A_2		31,60	45,80	9,10	12,70	1,00	Red-brown	Sandy loam
	B		34,10	50,20	7,30	7,95	0,55	Red-brown	Sandy loam
11	A_1	Hutton	30,40	35,35	13,23	18,40	2,38	Dark-brown	Sandy loam
	A_2		33,20	39,50	12,50	13,10	1,40	Dark-brown	Sandy loam
	A_3		28,15	38,10	16,30	15,90	1,30	Dark-brown	Sandy loam
20	A_1	Hutton	27,24	44,05	10,46	12,93	1,50	Dark-broum	Sandy loam
	A_2		37,65	45,40	7,70	8,44	0,95	Dark-brown	Sandy loam
	B		26,65	53,75	10,50	8,25	0,80	Light brown	Sandy loam

Soil samples were designated A_1, A_2, B and A_3 to record the horison from which they were taken. A_1 was taken from the A horison top soil, A_2 from either the lowest layer of the A horison or the top of the B horison, B from the B horison only. A_3 was taken in cases where the B horison was not reached.

TABLE 2. Soil reaction (pH), available phosphorus (ppm), organic matter (%) and total nitrogen (ppm) given for three sampling depths: S_1 = 0-5 cm ; S_2 = 10-20 cm ; S_3 = 30-40 cm. Means and S.E. calculated from three replicates.

PROFILE	Soil pH			Available P (ppm)			Organic matter (%)			Total N (ppm)			VEGETATION
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	
2	3,73	4,03		13,00	15,90		7,23	1,63		940,3	212,3		FYNBOS
1	3,75	3,67		13,03	9,80		4,43	1,63		684,8	205,0		FYNBOS
8	4,27	4,25	4,46	6,33	7,83	4,93	10,33	5,80	2,73	704,0	1971,0	198,2	FYNBOS
3	3,61	3,58		16,53	16,03		6,67	4,50		1051,3	378,0		FYNBOS
5	3,34	3,22		6,43	3,67		19,60	4,03		2323,0	443,3		FYNBOS
4	4,22	3,95		6,53	3,73		14,70	3,83		1606,0	364,3		FYNBOS
7	4,01	4,40		11,80	7,60		21,30	8,63		2753,3	1225,3		FYNBOS, SCRUB
9	3,77	3,86		7,80	6,13		5,60	4,72		907,7	212,3		FYNBOS, SCRUB
6	4,42	4,50		13,80	2,83		16,50	7,77		3705,3	1355,7		FYNBOS, SCRUB
10	4,40	3,99	4,18	15,27	11,40	9,03	17,67	3,97	1,60	3084,7	638,3	133,0	FYNBOS, SCRUB, FOREST
19	5,60	4,70	4,77	5,00	3,30	2,90	17,70	8,36	8,07	3551,0	1628,3	1099,0	FYNBOS, SCRUB, FOREST
18	4,91	4,28	4,30	7,87	2,60	2,37	24,70	10,47	8,73	611,3	625,3	256,7	SCRUB, FOREST
17	4,93	4,66	4,52	3,83	1,80	3,20	25,23	16,30	14,90	5553,3	3721,3	775,3	SCRUB, FOREST
16	4,95	4,33	4,55	9,00	4,50	2,73	13,77	9,63	7,00	3038,0	1705,7	1332,3	SCRUB, FOREST
12	6,08	5,12	4,80	2,37	4,27	2,37	31,90	23,33	22,37	4508,0	4295,7	3537,3	FOREST
16	5,24	4,12	4,23	15,60	8,23	6,43	23,53	11,07	6,83	6916,0	3007,7	1376,7	FOREST
14	5,00	4,32	4,29	9,53	4,03	2,60	17,40	13,10	10,57	3514,0	2214,0	1066,3	FOREST
13	6,10	5,35	4,52	11,83	4,37	2,10	20,07	13,00	7,83	4260,7	174,1	1155,0	FOREST
11	4,82	4,34	4,37	10,00	4,30	4,93	18,33	11,73	14,60	3614,0	2499,0	2746,3	FOREST
20	5,45	4,89	4,90	4,00	1,60	2,10	26,30	18,32	15,50	3649,0	2239,0	1865,0	FOREST

TABLE 3. Description and quantities of litter on fynbos, scrub and forest plots. Quantities are means of four replicates.

PLOT	Amount (g per 0,25m^2)	Description	Vegetation
2	28,0	Ericoid leaves and flowers, twigs.	Fynbos
1	27,2	Ericoid leaves and flowers, twigs.	Fynbos
8	41,9	Ericoid leaves, flowers, twigs. Tree leaves, _Leucospermum_ inflorescences.	Fynbos
3	35,4	Ericoid leaves, flowers, twigs. Tree leaves, _Acacia_ leaves, branches.	Fynbos/scrub
5	23,0	Ericoid leaves, flowers, twigs. Tree leaves and branches.	Fynbos/scrub
4	45,6	Ericoid leaves, flowers, twigs.	Fynbos
7	38,8	Ericoid leaves, tree leaves, twigs, bark.	Fynbos/scrub
9	34,5	Ericoid leaves, flowers, twigs. Tree leaves, bark. _Leucospermum_ inflorescences, _Acacia_ seeds.	Fynbos/scrub
6	58,4	Ericoid leaves, twigs. Tree leaves, bark, twigs.	Fynbos/scrub
10	77,0	_Virgilia_ leaves, ericoid twigs, bark.	Fynbos/scrub
19	50,0	Forest tree leaves, twigs, seeds, fynbos and _Acacia_ leaves.	Scrub/forest
18	24,53	Forest tree leaves, twigs, seeds, scrub leaves	Scrub
17	43,6	Forest tree leaves, seeds, twigs	Scrub/forest
16	53,3	Forest tree leaves, seeds, twigs	Forest
12	75,6	Forest tree leaves, Quercus leaves. Twigs, bark and branches.	Forest
15	36,2	Forest tree leaves, twigs, seeds	Forest
14	66,0	Forest tree leaves, twigs, seeds	Forest
13	33,4	_Quercus_ leaves mostly, forest tree leaves, twigs, bark, seeds	Forest
11	49,6		
11	49,6	Forest tree leaves, twigs, seeds. _Quercus_ leaves.	Forest
20	47,6	_Quercus_ leaves mosstly, forest tree leaves, twigs, bark, seeds	Forest

DISCUSSION

From the literature, there is ample evidence that nutrient-poor soils often support vegetation of high diversity, as for example the tropical forests, heather communities in Britain, Australia and California (Philips 1959, Beadle 1966, Chapman 1967, Ashton 1976). These soils are not necessarily poor in all nutrient substances. Nitrogen content, organic matter and other necessary elements may be present in relatively high concentrations (Philips 1959, Schmidt & Schmidt 1965). It is, however, the elements in lowest supply which should be considered in a discussion of soil fertility and how it may affect the vegetation. In all the above-mentioned examples of diverse vegetation, the soils are characterized by a limited supply of readily soluble phosphorus compounds to the plant. This situation may exist even though there may be high concentrations of phosphorus containing substances in the soil, these being 'unavailable' through fixation (Salisbury 1958).

An example of vegetation growing on poor soils which is particularly relevant to the fynbos situation, is that of the Australian sclerophyll, often quoted by Australian workers (Wilde 1959, Beadle 1966, 1954, Ashton 1976, Loveless 1961). This vegetation type resembles the fynbos in morphology, both being characterized by sclerophylly, and floristically there seems to be a close enough link to support a common origin in the distant past. The Australian and South African sclerophyll also share some aspects of their ecology, notably occurrence on acidic, nutrient poor soils which are sandy and have originated from sandstones and granites. The rôle of fire in the nutrient cycling of these two vegetation types have not been thoroughly investigated, but seems to be an important factor in both.

Aquestion which is very pertinent to this investigation of a possible vegetation-soil correlation is: why are these soils acidic and nutrient-poor? Does the answer lie with the soil forming factors or the vegetation ? Considering, on a global basis, the tremendous variety in climate, land configuration, geology and other factors instrumental in soil genesis, as well as the fact that these tend to interact differentle according to local conditions, one may expect a similar variety in the resultant soils. It also follows that in some cases, one factor, for example climate, could be the overriding influence on weathering, secondary changes like laterization, etc. of the soil.

Wilde (1958), Lamprecths (1974) and MacVicar (1975) stressed the point that parent materials play a dominant rôle in the nature of the soil. In Australia, this view was supported by the outcome of a survey of soil and parent material. Wilde (1958) found that phosphate-deficient, acidic soils were derived from granite which had a low average phosphorus content (0,155 % P_2O_5) as compared to basalt (0,428 % P_2O_5) which gave fertile soils. The method used in the analysis is now out of date, but the results nevertheless demonstrated the importance of the parent material in soil genesis. In South Africa, sandstone of the Table Mountain Series and granites produce coarse, acidic sandy soils for most part, but as yet no investigation has been undertaken to testify for the influence of parent rock on soil nutrient status.

The process of weathering is important. The mediterranean climate of the Western Cape favours mechanical weathering through having a long dry, hot period and a cold, wet period. Mechanical weathering gives rise to coarse, poorly-textured soils (Daubenmire 1959), which are prone to leaching especially during the period of winter rain. The profile data of Table 2 demonstrates the effect of leaching on soil nutrient levels, by the distinct lowering in values for phosphorus, nitrogen, and organic matter of the subsoils. The topsoil is the main source of nutrient recovery.

Lamprechts (1974) claimed that the Western Cape soils are podzols. This may be true for some other areas, but less so for the soils of Kirstenbosch. The present data rather suggests that the Kirstenbosch soils are either non-podzolised or at most, weakly podzolised. None of the soil profiles exhibited a strongly leached A_2 horison and an accumulative B horison, which is a characteristic feature of podzols Daubenmire 1959, Nye 1954) Podzols are often considered as being acidic only. It was, however, demonstrated that calcereous podzols do occur and thus soil acidity is no indication of podzolisation (Nye 1954).

During plant succession one may expect soil development due to the vegetation. This accentuates the tendency of soil types to form a mosaic pattern where topography and geology are sufficiently diverse. In the study area there is evidence of variation in the soil even within the same soil form.

The fynbos profiles (profiles 1 through 10) are all of Fernwood Form in various stages of development. Profiles 8 and 10 are examples of a well developed Fernwood Form, as shown in an orthic A horison with two layers. All other fynbos profiles have a simple orthic A horison over the B horison. Profiles 6 and 7 occupy a peculiar position in the range of soils. In colour they are similar to the forest soils, but as there are no other indications of an affinity with the soil of the forest, they were tentatively called Fernwood Form. It is possible that that area was previously covered with pine or forest species which changed the properties of the original sandy soil. This is also suggested by the higher values of phosphorus, nitrogen and organic matter as compared with the less developed Fernwood profiles. In nutrient status and pH profiles 6 and 7 rather relate to profiles 8 and 10(table 2).

Profiles 18 and 19 were taken in areas with mixed scrub and some forest elements. Profile 19 is of Fernwood Form but of higher nutrient status, that is in nitrogen and organic matter but not phosphorus,than the other Fernwood soil profiles. This may be related to the presence of forest species and a slightly higher litter production, where the litter consists of forest material (Table 3) as opposed to fynbos material in the other plots. The pH of the soil there,is also higher than in the pure fynbos soils.

Profile 18, being of Longlands Form, is the only one with a distinct clayey appearance. This is attributable to derivation from granite which often gives rise to clay soils depending on local conditions. Leaching, mottling indicate a possible fluctuating water table which could have provided the circumstances for clay to be dominant in this small area. Nutrient levels in this profile is of the range of the fynbos soils, but organic matter is remarkably high. On the plot there was evidence of felling. If, previously, a large tree had grown on the plot (there was a large tree stump), this could partly explain the higher organic matter content which would have been kept at that level by the scrub and some forest elements now growing there.

The soil in the forest is best developed both in terms of structure and nutrient content. Organic matter is present in much higher amounts than in the fynbos soil, and at lower depths as well. The humus content of the forest soils is probably much higher than that of the fynbos soils. This is difficult to assess quantitatively, because it is hard to draw a definite distinction between fully decomposed and partly broken down organic matter which constitutes the humus.

The forest profiles (profiles 11 through 17 and 20) are of the Hutton Form. The soils are loamy and have a higher clay sontent than the fynbos soils. Granite contributed substantially to the formation of these soils, whereas the fynbos soils are clearly of a sandstone origin.

A much neglected aspect of the ecology of nutrient-poor soils is the rôle of soil organisms in soil genesis and nutrient status. Nye (1954) suggests that these organisms may play an important part in podzolisation. Experimental and ecological research have indicated that in acidic soils the activity of the bacteria involved in nutrient recycling is inhibited (Ayanaba & Omayuli 1975), Barber 1967). The activity of micro-organisms influence the availability of phosphorus to the plant, for example, by fixation as organo-phosphorus, phosphates are made less available. Barber (1967) showed thai this becomes more marked as the pH of soil rises towards alkalinity. On the other hand, some mineralizing bacteria are acidophilic (Low pers. comm.) and their activity may make more phosphorus available to the plants in acid soils. This, then, could counteract the effect of the fixation of phosphorus by soil particles at low pH (Nye 1954) and micro-organisms in their bodies.

Soil fungi become the dominant organisms in acidic soils (Harley 1970) . Ayanaba & Omayuli (1975) found this to be the case in sandy, acidic soils of savanna. This appears to be consistent with the fact that mycorrhizae (fungi assosiated with the roots of higher plants) have been found in association with several fynbos species as well as forest species, notably, members of the Ericaceae (Low pers. comm.) However, one has to be cautious in interpreting such a finding in terms of soil pH as it is known that soil conditions are considerably modified in the rhizosphere. The presence of a mycorrhizal association, increases the uptake of phosphate and nitrate of the host roots through increased absorption area (Harley 1970). This implies that the host plant will have a competitive advantage by being able to utilize low nutrient levels more efficiently. Mycorrhizal associations are not the only possibilities on root modifications of the fynbos and forest in response to low nutrient levels. Several members of the Proteaceae develop 'proteoid' roots in soil with phosphorus deficiency (Grundon 1972). The possibility that this is a response to the water status of the soil, I.E. dryness, was investigated, but not proved (Low pers. comm.).

Soil fungi also reduce the amount of leaching from acidic, sandy soils (Cowan 1975). However, nothing is known about the rôle and activity of soil fungi in either the fynbos or the forest, so that no more can be said about this aspect of their function in the soil system.

The nature of the litter and the amount produced is another important aspect of vegetation ecology, especially in the field of dynamic ecosystem ecology. The litter is, ultimately, the only way by which the nutrients taken from the soil by the vegetation, can be recycled. Stock (1976) suggested that in fynbos we find what may be called 'tight' nutrient cycling (sensu Whittaker), which implies that any excessive losses of nutrients from the system cannot be 'afforded'. However, for a statement such as this to be proved true for the fynbos ecosystem, an extensive study of nutrient cycling, for example, by using radio-active tracers, is required.

It is the nutrient status of the plants and litter, which is going to determine the extent of soil enrichment which is to take place. There is reason to believe that the fynbos litter has a low phosphorus and protein (i.e. nitrogen) content. This follows from the finding that sclerophyll leaves of vegetation growing on nutrient-poor soils have a lower phosphorus and fprotein content than mesophytic leaves (Loveless 1961) of Australian vegatation. However, no evidence of this kind is available for the fynbos and forest to indicate similar differences in these nutrients. A qualitative difference has nevertheless been demonstrated to exist between the fynbos and forest litter (Table 3), which suggests that an investigation of the chemical properties of the litter should prove worthwhile.. This, together with data on actual quantities produced and possibly knowledge of the rate of incorporation into the soil, should adequately explain any difference in nitrogen or phosphorus levels between the forest and fynbos.

Losses of nutrients like nitrogen and phosphorus inevitably lead to impoverishment of the soil. Leaching through rain and the volatilization of nutrients through fire, as well as removal of dead plant material could amaount to this. Robertson & Davies(1956) and Chapman (1967) found that nitrogen and phosphorus is lost in minimal amounts from the litter of British heath . This is difficult to interpret, as no indication was given of the nature of the loss.1 If due to leaching, the nutrients were probably already mineralized and as such not part of the actual litter. Chapman (1967) and Allen (1964) reported exeptionally high losses of nitrogen to heather ecosystems due to volatilization by burning.

Considering the data obtained from the soil analysis and vegetation survey, it becomes clear that some relation exists between the occurrence of groups of vegetation and the general soil nutrient status. In broad terms, a high nitrogen and organic content, as well as a better developed soil are indicative of a forest vegetation, while low values for nitrogen and organic matter are associated with the fynbos community. Lower values for available phosphorus in the forest soil may be due to fixation as organic forms. As the amount of fixation as organic forms, in soil samples , could not be determined, a direct correlation of phosphorus with vegetation is not possible. The results revealed however that the nutrient status of the forest and fynbos, in terms of phosphorus levels, is of the same order. This ties in with the presence of root modifications due to nutrient deficiency, in the roots of both vegetation types.

The vegetation of the study area conveys the general impression of severe disturbance. This is, of course, unavoidable , as Kirstenbosch is under management control and moreover a tourist attraction. In the fynbos the occurrence of many footpaths in the area, caused the vegetation to have a clumped appearance. Thus, groups of Erica species and associated plants are interrupted by patches of Pteridium aquilinum and various small herbaceous species usually found during the first stages of regeneration. Furthermore, the are many patches of dead fynbos, which may either have died naturally due to senescence or have been partly destroyed by humans visiting the area.

A similar situation is found in the forest and adjacent areas. Here, large open spaces interrupt the otherwise continuous vegetation. The spaces are the result of tree-felling, upon which the litter was heaped together in stacks to be removed later. In these open patches, the following herbaceous and introduced species are common: Solanum nigrum, Achyranthes aspera, Cedronella triphylla, Senecio rigidus, Polygala myrtifolia, Briza spp, Drougetia ambigua, Senecio ? subcanescense. These plants grow on the forest soils, but not on the fynbos soils. A possible reason might be preference for a high nitrogen content in the soil.

The distribution of certain species is suggestive of a successional sequence, with fynbos on the one and forest on the other extreme. This confers that the distrubutional patterns, on a local basis, overlap considerably in some species while others are localized. In relation to the soil nutrients, such species should have a wider range of tolerance to soil nutrient levels, while the others are probably restricted in part by their preference of certain soil nutrient levels. The 'differential' species in this regard are, in the fynbos, all Erica spp, Leucospermum conocarpodendron, Blaeria sp, Pentachistis sp, and in the forest, Diospyros whyteana, Rapanea melanphloes, Halleria lucida, Rubus fruticosus. The 'wide' group which could be extracted from the table (Appendix 1) on grounds of presence in many sample plots, and thus all the soil conditions known from the investigation, in cludes the following important species: Podalyria calyptrata, Oxalis eckloniani, Cassine peragua and Kiggelaria africana and Virgilia oroboides. Whether soil nutrient status is indeed an important factor in their distribution, may be questioned. They occur on both forest and fynbos soils, which differed mostly in the nitrogen levels, but also in water availability. It is possible that water availability and shading are factors to be considered in seeking an explanation for this relatively wide range in occurrence. A pont to notice, is the presence of shade-giving forest precursor species (Plots 10, 18)where seedlings of forest species are found. This association rather points towards an intolerance to high insolation and explains the absence of these seedlings in other open parts of the fynbos. It is possible that during the summer heat, many of these seedlings may succumb, thus accounting for the absence of a definite successional trend leading to forest from the extant precursor forest in the fynbos area. The rêle of shading is also evident from the Following example. Rhus tomentosa which grows in the forest has a ecotype with large, mesophytic leaves, found mostly in shade, while in the open, in fynbos the ecotype has small hairy leaves.

Only a long term study of plant succession in the Kirstenbosch 'back garden' should show whether the continuous disturbances experienced by the vegetation has altered the course of succession. In this regard, the history of the vegetation, concerning previous invasions by alien vegetation, should also be considered. This is especially important from the standpoint of soil conditions. Both fynbos and pine tend to lower the pH of the soil, while Acacia tends to increase the pH of soil. A longterm study should reveal eventually whether nutrient levels are more important in succession than, for example, moisture availability. As so often seems to be the case in nature, heretoo,the interactions of several soil factors are more likely to provide us with the answers.

SUMMARY

A survey of soil nutrient status and vegetation was performed in the 'back garden' of Kirstenbosch. The soil samples were analysed for available phosphorus, total nitrogen, organic matter, soil reaction by chemical methods. Soil particle sizes were determined using a sieve method. Samples of litter was collected to show a qualitative difference between the litter of forest and fynbos.

The survey revealed that the nutrient status of the forest and fynbos differs mainly in terms of total nitrogen levels and organic matter, this being higher in the forest soils than in the fynbos. The forest soils are on the whole better developed than the fynbos, which may be due to the collective action of vegetation during succession.

Disturbance is an important factor in the distribution of many species in the area, and may have led to introduction of minor invading species, notably, herbaceous types. These are present in all areas where secondary succession is in progress after a disturbance, for example, tree-felling or eradication of alien vegetation.

The aim of the study was to provide some idea of the nutrient levels in fynbos and forest soils, and, hopefully will serve as a general guide in further investigations of the nutrient status of our fynbos and forest.

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APPENDIX 1 : Final table of Braun-Blanquet vegetation analysis. Cover-abundance values and environmental data.

Plotnumber	2	1	8	3	5	4	7	9	6	10	19	18	17	16	12	15	14	13	11	20
Species list																				
Pentaschistis sp	(*)	+																		
Cliffortia polygonifolia		(+)	1						+											
Diospyros glabra	+	(+)	+						(+)											
Erica pluckenetii		(+)	(+)																	
Leucospermum conocarpodendron			(+)	(+)	(+)	(+)		(+)												
Simocheilus sp				3	2	3		1												
Erica imbricata				(+)	1	+														
Widdringtonia nodiflora							2	(+)	(+)											
Leucadendron argenteum							(+)	(+)	(+)											
Blaeria sp	+	2	1	1	1	1	+		+											
Stoebe cinerea	1	1	2		1	1	2			(+)										
Erica hispidula	3	2	2	2	2	1														
Erica hirtiflora	1	(+)					1	+	+	1										
Cassythe ciliolata	+	+	+		+		(+)	+	(+)	1										
Cyphia incisa	(+)	+	+				+		+											
Diospyros whyteana											2	2	3	2	1	22	3	3	2	3
Rapanea melanphloes											(+)	1	1	3	3	+	1	2	3	3
Halleria lucida											1	2	+	3	2	2	2	+	+	2
Drougetia ambigua (annual)											1	1	2	1	1	2	2	2	4	1
Canthium ventosum									(+)		2			1	1	+	+	1	2	2
Rubus fruticosus											+	+	1	+	+	+	+	+	+	1
Maytenus heterophylla										1	1	+	1	1		+	1		1	
Dolichos gibbosus										+		+	(+)	(+)	+	+	(+)	(+)	+	
Ehrharta erecta										+	1	+	1	1	+	1	+	(+)		
Blechnum australii													1	(+)		+	1		+	+
Asparagus scandens										+		+		(+)	+			+	+	1
Quercus robur											1	+	+			+		(+)		(+)
Achyranthes aspera													+	(+)	+	(+)	+	+	+	
Solanum nigrum											(+)	+	+			+	(+)			
Cedronella triphylla													(+)		(+)	1	(+)		+	
Zanthedeschia aetheopica												+	+			+	(+)		+	
Anthericum spp											1	+				+				
Canthuim mundianum																+		+		(+)
Fumaria muralis												+					(+)		+	
Senecio rigidus										+					(+)		(+)			
Secamone alpinii														(+)	+					+
Rhus tomentose	1	1	+	+	(+)	(+)	1	1	2	2	+	2	(+)	(+)	(+)					
Passerina vulgaris	1	1	1	1	1		+	2	1	(+)	1	1								
Pteridium aquilinum	1	1	2	1		+	1	2	1	1	+									
Acacia saligna	+		1		1	(+)	1		1		(+)	+	+							
Ficinia filiformis	+	1	+		1	(+)	1		1		1	+	(+)							
Maytenus oleoides	(+)	(+)	1		(+)	(+)	(+)	1		+		1								
Myrsine africana	(+)	(+)			(+)		1	+		1	1	1								
Metalasia muricata			1		+		1	+		(+)	(+)									
Stoebe sp.	(+)		+						(+)	1	(+)									
Asparagus thunbergianum			1				(+)	+			(+)	+								
Selago corymbosa			+				(+)				+									
Senecio subcanescens x ?			+							+	(+)									
Ursinia dentata	(+)						+		+											
Rubus pinnatus				(+)					1	+										
Ficinia trichodes			+				1				+									
Chironia baccifera			+							+	+									
Briza moxima (+ minuta? annual)		1									1	+								
Helichrysum capitellatum	+										+	1								
Cassine peragua	(+)						+	+	+	+	+	+	3	1	1	(+)	2		1	2
Kiggelaria africana							(+)		+	+	3	2	2	(+)	3	2	3	2	2	2
Olea capensis					(+)				+	1		+	(-)	(+)	1	(+)	1		1	2
Virgilia oroboides							+		1	3	+	3	3	(+)	(+)	3	2			
Fagelia bituminosa							(+)		+		+						(+)			
Hermannia hyssopifolia							(+)					+					(+)			
Polygala myrtifolia							(+)			(+)	(+)	(+)								
Oxalis eckloniani	+	+	1		+	(+)	+	1	1	+	1	1	3	1	1	2	1	1	1	1
Podalyria calyptrata	(+)	(+)	(+)	1		(+)	3	3	2	2	1	2	(+)		(+)	(+)	(+)	+	(+)	
Chasmanthe aetheopica	+	+			(+)	(+)	+	+	1	1		+	+		+		+		1	(+)
Knowltonia capensis	(+)				(+)						1	1	+	+		(+)	1	1	+	(+)
Aristea spiralis	+	+										+								
Watsonia spp.		(+)								1		+	+	+						
Slope	S	S	S	S	S	S	M	M	S	S	M	M	M	M	S	G	G	S	M	S
Aspect	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	E	SE	SE	S	SE	SE	SE	SE
Soil depth (metres)	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,5	1,0	0,5	0,5	0,5	0,3	0,5	0,5	0,5	1,0	0,5	1,0
Geology	T/G	T/G	T/G	T/G	T/G	T/G	T/G	T/G	T/G	T/G	G	G	G	G	G	G	G	G	G	G
Rock size		L			L					L		S/L	S/L	L	S/L	S/L	S/L	S/L	VL	L
Rock cover (B-B scale)		1			1					+		1	1	2	1	1	2	1	2	1
Habitat	D	D	D	D	D	D	D	D	D	D	D	TM	TM	SM	TM	TM	TM	TM	TM	TM

Abbreviations:

<u>Slope</u>: S = 16,5 - 26,5°; M = 8,5 - 16,5°; G = 3,0 - 8,5°

<u>Aspect</u>: S = South; E = East

<u>Geology</u>: T = TMS; G = Granite

<u>Rock Size</u>: L = 0,60 m; S = 0,15 m

<u>Habitat</u>: D = Dry; TM = Temporary moist; SM = Seasonally moist

SPECIES GROUPINGS IN TABLE (APPENDIX 1)

Acacia saligna + Acacia longifolia = Acacia saligna
All Anthericum spp = Anthericum spp
All Watsonia spp = Watsonia spp
Briza minor + Briza maxima = Briza maxima
All Aristea spp = Aristea spiralis

SPECIES INFREQUENT TO FOREST AND FYNBOS AREAS

Cluytia pulchella	18 : 1
Brabeium stellatifolium	19 : 1
Senecio subcanescens	17 :(+); 18 : 1
Olea africana	18 : 1
Pelargonium cuculatum	17 :(+)
Senecio foeniculoides	15 : 1
Ehrharta calcygina	17 : 3; 2 : +
Asplenium sp	13 : +; 15 :(+)
Scutia indica	13 :(+) 19 : +
Muraltia heisteria	10 :(+) 19 : +
Dichesma sp	10 :(+)
Oxalis purpurea	18 : 1 9 : +
Erica baccans	8 : 1
Leptospermum laevigatum	8 :(+)
Phylica stipularis	8 :(+) 9 :(+)
Ficinia acuminata	9 : 1
Senecio elegans	9 : +
Bobartia indica	7 :(+)
Anthospermum ciliare	8 : 1
Chrysamthemoides monilifera	7 : 1 2 :(+)
Asparagus africanus	7 :(+)
Plagiochloe uniolae	7 : 1
Pellaea viridis	6 : +
Wachendorfia paniculata	6 : + 7 :(+)
Ehrharta capensis	6 : +
Pinus pinaster	5 : + 6 :(+)
Leucadendron argenteum	6 :(+) 7 :(+)
Psoralea aculeata	5 :(+)
Erica mauritanica	2 :(+)
Cyphia volubilis	2 :(+) 5 :(+)
Rhus lucida	2 : 1 5 :(+)
Willdenowia luceana	1 : 1 5 : +
Thesium strictum	2 :(+) 5 :(+)
Lichtensteinia lucera	2 : +
Ursinia anthemoides	2 : +
Selago serrata	1 :(+) 2 +
Restio cuspidatus	1 : +

REFERENCES

Allen, S.E. 1964 Chemical aspects of heather burning J. appl. Ecol. 1(2) : 347 - 368

Ashton, P.H. 1976 The vegetation of Mount Piper, Central Victoria: a study of a continuum. J. Ecol. 64(2): 463 - 480

Barber, P.A. 1967 Influence of pH on the uptake of phosphate by barley plants in sterile and non-strerile conditions. Nature 215: 779 - 80

Beadle, N.C.W. 1954 Soil phosphate and the delimitation of plant communities in Eastern Australia. Ecol. 35: 370 - 375

1966 Soil phosphate and its rôle in molding segments of the Australian flora and vegetation, with special reference to xeromorphy and sclerophylly. Ecol. 47: 992 - 1007

Campbell, B. 1975 Honours Project. Ecology.

Chapman, S.B. 1967 Nutrient budgets for a dry heath ecosystem in the south of England. J.Ecol. 55: 677 - 90

Daubenmire, R.F. 1959 Plants and Environment. John Riley & Sns New York

Esterhuizen, E. 1936 Regeneration after clearing at Kirstenbosch. J. S.A. Bot. : 177 - 185

Fourie, L.J. 1974 Minerale tekorte in Suid-Afrika. 3rd year seminar, UPE.

Grundon, N.J. 1972 Mineral nutrition of some Queensland heath plant. J.Ecol. 60 : 171 - 181

Harley, J.L. 1969 The Biology of Mycorrhizas

Jackson, M.L. 1958 Soil Chemical Analysis. Prentice Hall, Inc

Lamprechts 1974 Notes on fynbos soil and Soil Classification of South AFrica

Loveless, A.R. 1961 A nutritional interpretation of sclerophylly based on differences in the chemical composition of sclerophyllous and mesophytic leaves. Ann. Bot 25: 168 - 184

MacVicar, C.N. 1975 Introduction to the South African soil classification.

Moll, E.J. + Campbell, B. 1975 Table Mountain. A management and conservation report.

Nye, P.H. 1954 Soil pH: Facts and fallacies. Ecol. 35: 99 - 101

Omayuli & Anayaba 1975 Plant & Soil 43: 519

Cowan, M.C. 1975 Plant & Soil 42: 711

Philips, J. 1959 Agriculture and Ecology in Africa. Faber & Faber. London

Robertson, R.A. & Davies, G.E. 1956 Quantities of nutrients in heather communities. J.appl. Ecol. 2: 211 - 219

Schmidt, G. & Schmidt, U. 1963 Organic matter and N content of veld soils. Plant and Soil 19: 315 - 323

Stock, W.D. 1976 Honors Seminar. Ecology

Van Westhoff, & Van den Maarel 1973 The Braun-Blanquet Approach In: Ordination and Classification of Communities V. Dr. W. Junk b.v. Pub. The Hague

PLOT 1: FYNBOS - ERICA SPP., PODALYRIA CALYPTRATA, BLAERIA SP., RHUS TOMENTOSA (BACKGROUND)

PLOT 2: FYNBOS - ERICA HIRTIFLORA, PTERIDIUM AQUILINUM, PODALYRIA CALYPTRATA (BACKGROUND)

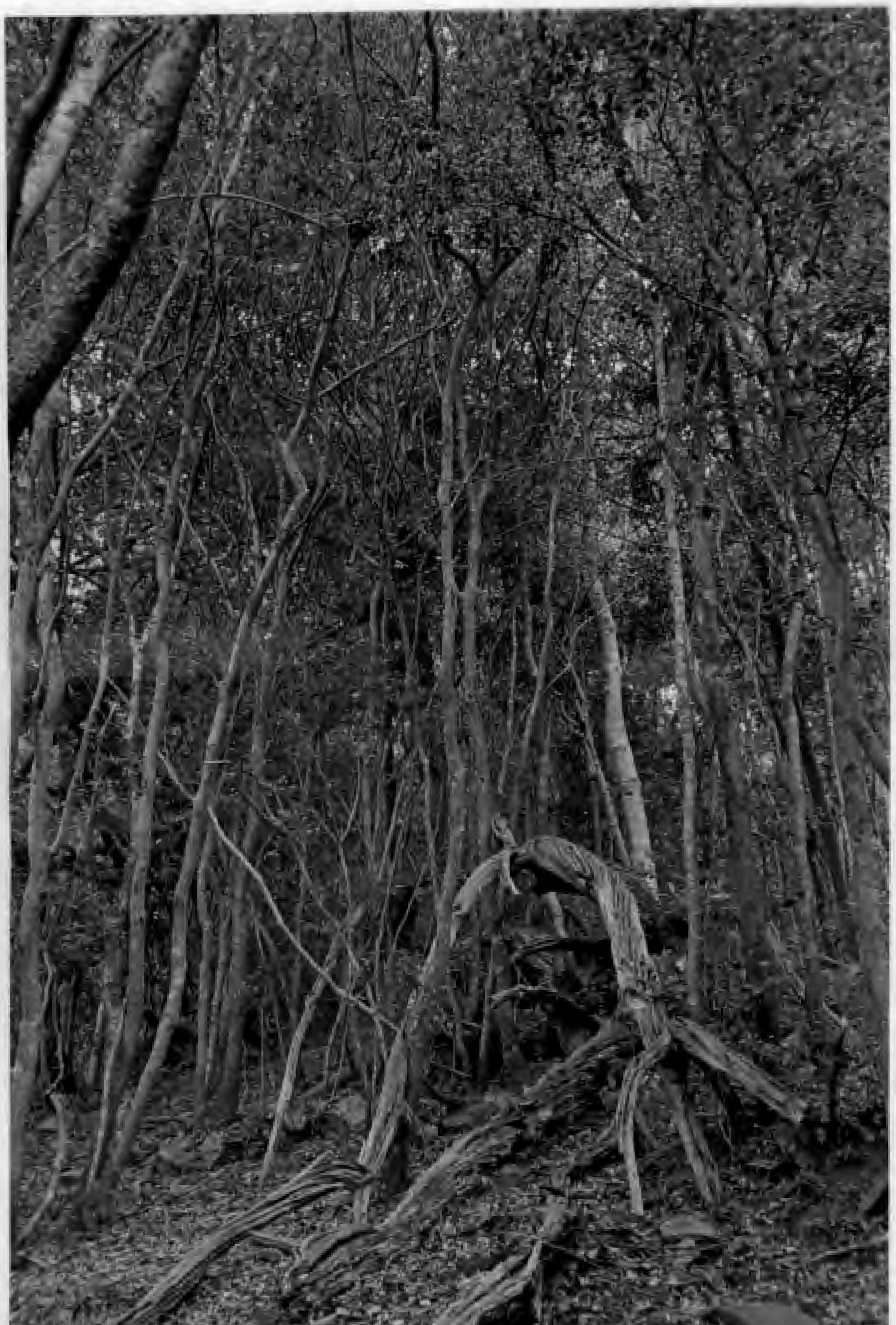
PLOT 3: FYNBOS/SCRUB – PTERIDIUM AQUILINUM, ERICA SPP., BLAERIA SPP, RHUS TOMENTOSA

PLOT 8: FYNBOS/[illegible] – PTERIDIUM AQUILINUM, LEUCOSPERMUM CONOCARPODENDRON, ERICA HIRTIFLORA
ERICA MAURITANICA, STOEBE SP.

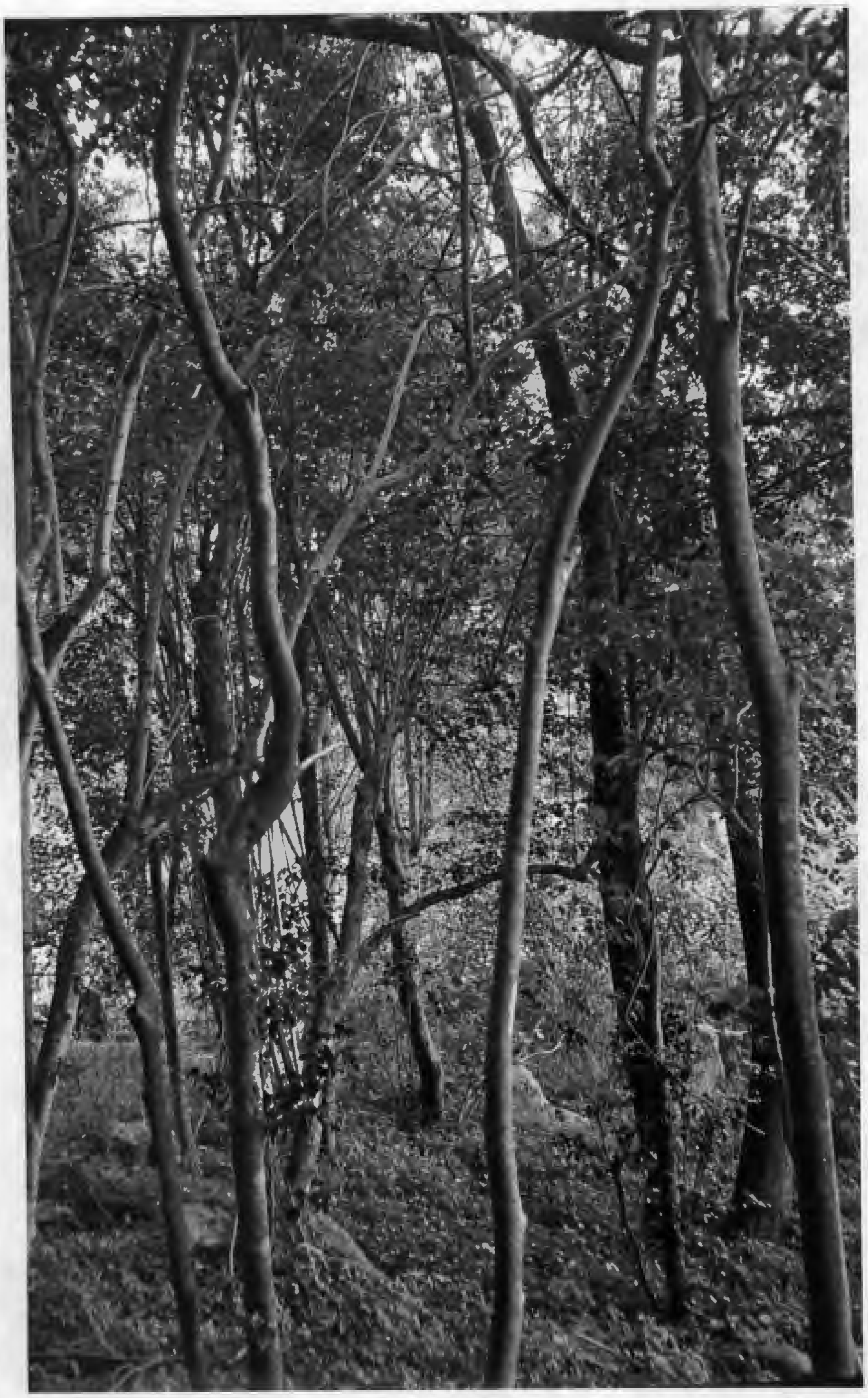
PLOT 9: SCRUB/FYNBOS - PODALYRIA CALYPTRATA, ERICA HIRTIFLORA, STOEBE CINEREA

PLOT 10: SCRUB/FYNBOS – PODALYRIA CALYPTRATA, RHUS TOMENTOSA, VIRGILIA OROBOIDES
METALASIA MURICATA

PLOT 12: FOREST - KIGGELARIA AFRICANA, RAPANEA MELANPHLOES



PLOT 13: YOUNG FOREST - DISTURBED



PLOT 14: FOREST - DIOSPYROS WHYTEANA, HALLERIA LUCIDA

PLOT 16: FOREST - DIOSPYROS WHYTEANA, RAPANEA MELANOPHLOEOS